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Journal of the Council for Scientific and Industrial Research.

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Studies on Mineral Metabolism in Sheep.

1. On the Necessity to Supplement Cereal Grains with Calcium in Sheep Rations.

*By M. C. Franklin, M.Sc., Ph.D.(Cantab.), A.I.C.**

Summary.

A study has been made of the effect on the health of sheep of adding a supplement of calcium carbonate to a ration made up largely of cereal grains and their by-products.

Sheep fed on rations which did not contain the calcium carbonate supplement failed to develop normally. Stunted growth, a severe hypocalcaemia, gross abnormalities in dental development, and heavy mortality were among the changes observed. Adult sheep as well as weaners were seriously affected.

Sheep receiving a similar ration supplemented with calcium carbonate developed normally.

1. Introduction.

Periodically drought conditions are experienced in many parts of Australia. The feed shortage may become so severe that stockowners may be faced with two alternatives—provision of supplementary rations or serious losses among their stock.

Although there has been a considerable increase in fodder conservation in some parts, many graziers rely on purchased feed to tide their stock over periods of scarcity. It was inevitable, in view of the extent of cereal production in Australia, that grain, or concentrated mixtures containing a large proportion of grain, would form the bulk of such rations. Furthermore, the abnormal conditions imposed upon us by the war may bring about a still greater extension of the use of grain for stock feeding. This would help to alleviate the problem of storage and disposal of large quantities of wheat. Ease of handling, and the provision of maximum food value in the minimum quantity of material, are two further reasons why grains, and to a lesser extent their by-products, will continue to be used widely.

Obviously, therefore, it is important that we should correct any deficiency which may be present in rations consisting largely of cereal grain mixtures. That they are deficient in calcium is well known, but the effect of this deficiency on sheep has not been so fully appreciated.

Work which has been carried out at the McMaster Laboratory during the last two years has demonstrated the importance of adding calcium to a ration in which grain and grain by-products form a large part of the mixture. Particularly is this important for sheep receiving such rations under drought conditions, and for stud sheep receiving supplementary concentrates.

* An officer of the Division of Animal Health and Nutrition at the McMaster Animal Health Laboratory, Sydney.

2. Experimental Procedure.

In September, 1939, three groups of crossbred ewes and their lambs were placed under experiment. Each group, which consisted of six ewes and six lambs, was fed separately and rationing, during the early part of the experiment, was as follows:—

Group 1.—Basal ration only.
Group 2.—Basal ration + ½ per cent. sodium oxalate.
Group 3.—Basal ration + 1 per cent. calcium carbonate.

The basal ration was made up of the following parts by weight:—Wheaten chaff 44, bran 25, oats 25, linseed meal 5, common salt 1.

This mixture was fed throughout the experiment and contained approximately 0·16 per cent. CaO and 0·90 per cent. P_2O_5. Slight variations occurred among different batches of feed.

Ewes and lambs in Group 2, receiving sodium oxalate in their ration, behaved similarly to those in Group 1, and therefore these two groups will be combined for some of our considerations. We do not propose to discuss in this paper reasons why the sodium oxalate itself had no adverse effect on the animals in Group 2.

Lambs in all groups were weaned at two and a half to three months of age on 10th November, 1939, and were then carried on in their respective groups until 30th May, 1940, when they were approximately nine months old. Thereafter five weaners from Groups 1 and 2 were given the basal ration plus 1½ per cent. calcium carbonate. The remaining three animals of these two groups were continued on the basal ration only. On 11th December, 1940, the ewes in Groups 1 and 2 were grouped together and continued on the basal ration alone.

Emphasis should be laid on the fact that throughout the experiment all animals were fed *ad lib.* Whenever all the food offered was consumed the ration was immediately increased. Food intakes were recorded continuously, but will not be dealt with here.

3. Results.

(i) *Effects on Live Weight of* (*a*) *Weaners, and* (*b*) *Ewes.*

(*a*) *Weaners.*—Only post-weaning weights are considered. Owing to a certain number of deaths, which will be referred to later, the number of animals will be found to vary in different tables. Results are shown in Tables 1 and 2. The live-weight changes recorded in Table 2 are illustrated in Fig. 1.

Up to 30th May, 1940, four weaners had died in Groups 1 and 2 and several others were in such poor condition that further losses appeared inevitable. On this date the five worst-conditioned (but not necessarily lightest) animals were placed on the basal ration plus 1½ per cent. calcium carbonate. At this stage A986 was able to stand only with difficulty. The remaining three weaners continued on the basal ration; two—X75 and X84—were dead within eighteen days.

The average live weight of the eight survivors in Groups 1 and 2 was 41·1 lb. on 30th May, 1940. This was the average weight of these same animals on 17th November, 1939. The six weaners in Group 3 increased in live weight over the same period from 41·3 lb. to 75·6 lb., an increase of 34·3 lb. per head.

TABLE 1.—LIVE-WEIGHT CHANGES OF WEANERS FROM 17TH NOVEMBER, 1939, TO 28TH MARCH, 1940 (132 DAYS).

Weaner Number.	17th November, 1939.	6th December, 1939.	16th January, 1940.	23rd February, 1940.	28th March, 1940.
Group 1.	lb.	lb.	lb.	lb.	lb.
Basal ration—					
X75	41	43	45·5	52	56
X79	34	34·5	36	37	36
A504	34	36·5	39	38	41
A989	46	42	49·5	49	51
Group 2.					
Basal ration + ½ per cent. sodium oxalate—					
X84	38·5	35	40·5	44	44
X94	44	36·5	38	41·5	42
A508	45	42·5	46	51	52·5
A984	34	37	35·5	38	39·5
A986	46·5	41	44	45·5	47
Total groups 1 and 2 ..	363	348	374	396	409
Average (nine animals) ..	40·3	38·6	41·5	44·0	45·5
Group 3.					
Basal ration + 1 per cent. calcium carbonate—					
X70	30	33·5	42·5	49·5	54
X71	42	46·5	60	68	70·5
X92	34·5	40	47	56·5	65
A982	38·5	39·5	46	53·5	58
A983	37·5	44·5	54·5	64·5	64
A988	65·5	74	84·5	92·5	95
Total	248	278	334·5	384·5	406·5
Average (six animals) ..	41·3	46·3	55·8	64·8	67·8

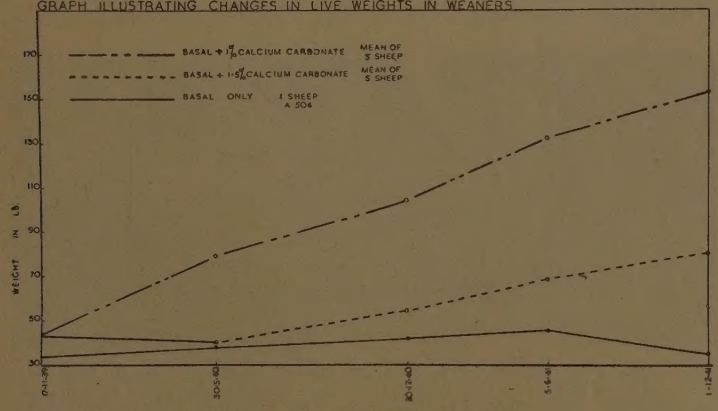

FIG. 1.—Showing the changes in live weight of surviving weaners between the dates 17th November, 1939, and 1st December, 1941.

TABLE 2.—CHANGES IN LIVE-WEIGHT OF ANIMALS SURVIVING ON 1ST DECEMBER, 1941 (APPROXIMATELY TWO YEARS).

Sheep Number.	17th November, 1939.	30th May, 1940.	30th December, 1940.	5th June, 1941.	1st December, 1941.
	lb.	lb.	lb.	lb.	lb.
Basal ration only—					
A504 (the only survivor) ..	34	38	42	45·5	35
Basal ration until 30.5.40, thereafter basal ration + 1½ per cent. $CaCO_3$—					
A989	46	43	54	68·5	81
X94	44	35	46·5	59	71·5
A508	45	47·5	62	73	77·5
A984	34	37·5	59	75·5	90
A986	46·5	37	49	65	81
Total	215·5	200	270·5	341	401
Average (five animals).. ..	43·1	40	54·1	68·2	80·2
Basal ration + 1 per cent. $CaCO_3$ during whole experiment—					
X71	42	78	101	127	146
X92	34·5	71	96	114	129·5
A982	38·5	68·5	87	117	144·5
A983	37·5	76	96	131	154·5
A988	65·5	103	142	172·5	193
Total	218	396·5	522	661·5	767·5
Average (five animals).. ..	43·6	79·3	104·4	132·3	153·5

The relative development of weaners in the different groups is shown in Fig. 2, reproduced from a photograph taken on 9th May, 1941. The animals shown were selected as the most representative animals from each group.

FIG. 2.—Showing representative weaners from the three groups receiving (*a*) basal ration only, (*b*) basal ration and later supplement of 1½ per cent. calcium carbonate, and (*c*) basal ration plus 1 per cent. calcium carbonate, respectively, arranged in order left to right. The live weights were 51·5 lb., 71·5 lb., and 125·5 lb., respectively.

(*b*) *Ewes.*--The ewes were full-mouthed and of varying age. With one exception—H976, a Dorset-horn ewe—all were crossbred Merinos. Changes in live-weight were not so spectacular as with the weaners, but the differences between the groups were no less definite, and are shown in Table 3. The ewes were fed *ad lib.* as were the weaners.

TABLE 3.—CHANGES IN LIVE-WEIGHT OF EWES FOR THE NINE-MONTH PERIOD 17TH NOVEMBER, 1939, TO 5TH SEPTEMBER, 1940.

Ewe Number.	17th November, 1939.	23rd February, 1940.	16th May, 1940.	5th September, 1940.
Basal ration only or Basal ration + ½ per cent. sodium oxalate—	lb.	lb.	lb.	lb.
H576	81·5	84	83	65
H605	93·5	108	113·5	73
H637	97	105	106·5	104
H643	72·5	99	106	100
H552	113·5	110	98·5	70
H599	82	92·5	93·5	81
H640	74	79	87·5	79
H669	102·5	109	106	88
Totals	716·5	786·5	794·5	660
Average (eight animals)	89·6	98·3	99·3	82·5
Basal ration + 1 per cent. calcium carbonate—				
H589	78	92	94	105
H609	93·5	106	117	117
H706	73	108·5	117	116·5
H718	73·5	96	100	107
H976	109·5	147	162·5	185
Totals	427·5	549·5	590·5	630·5
Average (five animals)	85·5	109·9	118·1	126·1

(ii) *Mortality Rate.*

Heavy losses occurred among the animals in Groups 1 and 2. The experiment was commenced with twelve weaners in these two groups. Three died after being fed on the basal ration for approximately four months, three more after seven to nine months, and one after 27 months.

The remaining five weaners of these two groups were changed over, when nine months old, to the basal ration plus 1½ per cent. of calcium carbonate. All survived, although their condition was extremely poor when the change-over was made.

One animal was lost from among the six weaners in Group 3, which received the basal ration plus 1 per cent. calcium carbonate during the whole experiment. This animal was severely hypocalcaemic for four months before its death. Reasons for this drop in serum calcium will be discussed in a later paper.

Losses among the twelve ewes in Groups 1 and 2 were also heavy. Three died within six months of the commencement of the experiment, three more within twelve months, another one at seventeen months, and three more approximately two years after the experiment was started.

One ewe out of the six in Group 3 died from some intercurrent cause unconnected with the ration approximately ten months after the experiment commenced.

(iii) *Serum Calcium.*

Only a limited consideration need be given here to the biochemical analyses which included regular estimations of serum calcium, magnesium, and inorganic phosphorus. These results will be discussed more fully in another place.

That disturbance of the calcium metabolism occurred in the experimental animals on the basal ration is obvious on consideration of the results of analyses. The mean values of serum calcium in the lambs before weaning in Groups 1 and 2 fell from 10·66 mg. and 10·93 mg. per 100 cc. of serum, respectively, on 14th September, 1939, to 6·68 mg. and 5·25 mg. on 8th November, 1939, whereas there was no fall in the values in the lambs in Group 3. The lambs were weaned on 10th November, 1939, and on 21st May, 1940, the mean serum calcium values for the three groups had fallen to 3·51, 3·52, and 8·73 mg., respectively.

The one surviving weaner which had been kept on the basal ration throughout the experiment showed a somewhat sudden rise in serum calcium from 5·02 mg./100 cc. on 5th May, 1941, to 8·22 mg./100 cc. on 5th June, 1941, and this rise continued to 10·10 mg./100 cc. on 4th August, 1941, after which there was a slight decline. This suggests a physiological adjustment on the part of the animal.

The serum calcium values in the weaners in Groups 1 and 2, which had been given a supplement of 1½ per cent. calcium carbonate from 30th May, 1940, gradually reached normality about five months after the addition of calcium to the diet.

The results obtained with the ewes were very much of the same order as those obtained with the lambs. The serum calcium values of the ewes receiving the supplement of 1 per cent. calcium carbonate remained approximately normal throughout, whereas the values for the ewes in Groups 1 and 2 fell very low, and in some individuals extremely low with fatal results.

The usual association of hyperphosphataemia with hypocalcaemia was general. Considerable increases in serum magnesium values were also noted, which is in keeping with the observations of Cunningham (1934) on the reciprocal relationship between serum calcium and serum magnesium levels in sheep drenched with a magnesium salt.

(iv) *Dental Development.*

At first a careful watch on dental development was not kept, but early in 1941 striking differences in the teeth of individual animals were observed. The observations were continued and the more outstanding abnormalities detected may be briefly described.

In the weaners, faulty development of the milk teeth, as illustrated in Plate 1, Fig. 1, failure of permanent incisors to erupt even at the age of 27 months, as illustrated in Plate 1, Fig. 1, and Plate 2, Fig. 1, and deformities of the gums with poorly-developed permanent incisors, as illustrated in Plate 1, Fig. 2, were among the abnormalities most commonly present in those receiving the basal ration. The provision of a supplement of calcium carbonate, after the animals had been on

the basal ration for nine months, in sufficient quantity to promote steady growth and development failed to correct abnormalities in dentition. With the addition of 1 per cent. of calcium carbonate to the ration throughout the whole experiment, development of the teeth was normal, as illustrated in Plate 2, Fig. 2.

4. Discussion.

The results obtained have demonstrated that a ration consisting of a large proportion of cereal grains, or their by-products, may adversely influence the health and general development, not only of weaners but also of adult sheep. The influence on the live-weight increase of weaners has been most pronounced. In animals which survived the initial feeding period, little change in weight occurred during an experimental period of twenty-seven months. The same ration with the addition of a supplement of calcium carbonate permitted normal development.

In the basal ration used in this work, the ratio of CaO to P_2O_5 was approximately 1 to 5·6. The addition of 1 per cent. of $CaCO_3$ would raise this ratio to 1 to 1·25. Whether this more suitable ratio of CaO to P_2O_5 would, in itself, account for the better development of those animals which received a supplement of calcium carbonate is not known. Various workers (Lowe and Steenbock, 1936; Lowe, Steenbock, and Krieger, 1939; Harrison and Mellanby, 1939; Common, 1941, and others) have drawn attention to the low availability of phytin P, in which cereal grains are relatively rich, and have demonstrated that phytin may immobilize much of the calcium present in foodstuffs. The experiments carried out by these workers, however, have been restricted to rats, dogs, and poultry. It is possible that in the ruminant, with its highly specialized type of alimentation, phytin P may be more efficiently utilized, and lowered absorption of calcium may not occur. Kay (1939) considers that the extensive fermentation which takes place in the alimentary tract of the ruminant probably ensures that phytin P is completely available for this type of animal. If Kay's views are correct, the CaO/P_2O_5 ratio, *per se*, could explain the different behaviour of animals in our experimental groups. We hope to investigate this in subsequent work.

Food intake of the individual sheep in our experiments has not been discussed, because examination of the data has not been completed and it has not been determined whether differences in live-weight increase were due wholly to quantitative differences in food intake, or partly to qualitative factors. Subsequent experiments (unpublished) indicate that in adult animals, at all events, live-weight increases on rations similar to those used in this experiment were identical, provided the same quantities of the calcium-supplemented or of the unsupplemented ration were consumed. This is in agreement with the findings of Swaminathan (1939) and those of Henry, Kon, and Thompson (1940), who demonstrated that varying the level of calcium intake had no effect on the biological value and the true digestibility of protein in a ration.

The biochemical changes in some of the groups were most pronounced. They will be discussed more fully in a subsequent publication. It will be sufficient to note here that on the basal ration

no difficulty was experienced in reducing the serum calcium to levels which must be regarded as pathological. It is interesting to note that animals which became severely hypocalcaemic were able to survive at these low levels for such long periods, and even to appear normal. Eventually a number of these hypocalcaemic animals died. In some instances death was somewhat unexpected and simulated hypocalcaemia in field cases; in others a rapid decline in condition preceded death. In some animals physiological readjustment resulted in a rise of serum calcium to values approaching normality. Metabolism experiments were not carried out on these animals, but earlier work (Franklin, 1934-5) suggests that this increase in the level of the serum calcium was accompanied by a steady and heavy withdrawal from the skeletal reserves.

With one exception, abnormal changes in the biochemical picture were prevented by the addition of calcium carbonate to the feed mixture.

Dental development has presented a most interesting picture. It is obvious that the serious deficiency of lime in cereal grain rations may influence dentition to an extent which must affect the subsequent development of sheep reared in the earlier stages of their lives on rations rich in cereal grains.

The wool weights recorded at the last shearing (1st December, 1941), when the sheep were carrying 15 months' wool, are of some interest. They were—

(*a*) Basal ration: 1 sheep (A504)—4½ lb. wool.

(*b*) Basal ration during first nine months to 30th May, 1940, and then basal ration plus 1½ per cent. $CaCO_3$: Average of 5 sheep—9½ lb. wool.

(*c*) Basal ration plus 1 per cent. $CaCO_3$: Average of 5 sheep—11½ lb. wool.

Finally, in view of the practical application of this work, it is desirable to refer briefly to means by which the abnormalities recorded here may be avoided under field conditions. Where adequate quantities of lucerne or other legume hay are fed along with grain mixtures, the high calcium content of the hay will correct any lack of calcium in the grain portion of the diet. Also, data published by Gurney (1938) suggest that where cereal grains are supplementing heavy scrub feeding the high calcium content of the scrub should satisfactorily offset the calcium deficiency of the supplement. However, where cereal grains form the bulk of the ration and other feed is not rich in lime, satisfactory results will be obtained by the addition of 1 lb. of finely-ground calcium carbonate to each 100 lb. of the grain mixture. Where this method cannot be adopted—for example when whole grain is fed in troughs or "trailed"—a calcium lick can readily be prepared, by the grazier, by mixing salt and finely-ground limestone in approximately equal proportions. If necessary, satisfactory consumption of such a lick can be encouraged by the addition of a small quantity of molasses.

5. Conclusions.

1. The provision of a suitable supplement of lime is essential in rations which contain a large proportion of cereal grains or their by-products.

2. Adverse effects noted in weaners fed on grain rations unsupplemented with calcium carbonate include retarded growth, the development of hypocalcaemia, hyperphosphataemia, and hypermagnesaemia, grossly abnormal dental development, and heavy mortality.

3. Weaners reared on such rations for the first nine months of life showed considerable improvement when a supplement of calcium carbonate was added to the ration thereafter, but still failed to develop normally. Particularly does this apply to the development of the permanent incisor teeth.

4. Adult ewes fed on the same unsupplemented ration may lose weight in association with a decrease in appetite and show blood changes similar to those noted with the weaners.

5. In the experiments here described the provision of 1 per cent. of calcium carbonate to the basal rations from the commencement entirely prevented any such abnormalities. Weaners fed on the calcium-supplemented rations developed normally, and ewes remained normal.

6. Acknowledgments.

The photographs were taken by Mr. E. Parrish, of this laboratory, whose assistance is acknowledged with pleasure.

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Notes on the Economics of the Northern Tuna (*Kishinoella tonggol*).

*By D. L. Serventy, B.Sc., Ph.D.**

Summary.

Additional evidence which has accumulated since the publication of Pamphlet No. 104 on the Australian tunas suggests that a promising beach-seine fishery for the northern tuna may be developed in the larger inlets and sheltered beaches of the eastern coastline. The fishery could be carried on during the late summer and autumn at least as far south as Sydney, with extensions to more southern grounds in some years.

The evidence indicates that fairly considerable bodies of tuna, in a spent condition following the spawning season, enter the shallow reaches of bays and ports, feeding voraciously on such school fish as pilchards. Whilst in shoal formation the tuna usually will not take the hook, but their habits suggest their capture by hauling nets and traps when close to shore, or circle nets when distant from the beaches. When the schools break up the individual fish may be caught by trolling, but this method does not appear to be an economic proposition in Eastern Australia. More successful results have been obtained in Western Australia, but the methods have not been extensively tested out.

The fish gives an excellent canned product.

In Pamphlet No. 104 it was stated that little reliable information existed as to the abundance and economic possibilities in the Australian area of the northern tuna or northern bluefin (*Kishinoella tonggol*). Though sport anglers were familiar with the fish, the Division's investigation vessel, the M.V. *Warreen*, had never caught it on her trolling gear. What evidence there was on the subject suggested that this tropical and sub-tropical species, which ranged down both the western and eastern coasts of Australia, reached its southernmost limit in the east at Sydney, and there were no records south of Port Hacking.

Shortly after the issue of Pamphlet No. 104 a considerable body of data came to hand which added quite extensively to our meagre knowledge of these fish, as well as raising some problems concerning their habits as related to fishing methods.

Distribution and Abundance.

On March 18 a catch of over a hundred northern tuna was made with a beach seine at Jervis Bay; this was followed by catches in similar manner at Merimbula on March 21, at Port Hacking on April 3, and at Bateman's Bay on May 16. In addition, nine fish caught on the Hawkesbury River appeared on the Sydney market on April 16. These tuna were variously reported by fishermen and State Inspectors either as yellowfin or southern bluefin, but personal examination of samples of the Jervis Bay and Port Hacking catches determined them as northern tuna, and further inquiries concerning the remainder produced satisfactory evidence that they were the same species.

* An officer of the Division of Fisheries.

This was the first occasion on which such catches had been made since the Division of Fisheries began its investigations on this coast in May, 1938, but it appears that the species regularly occurs in the Sydney area and for some distance further south in the late summer and autumn. It is generally agreed, however, that fish were unusually abundant in the 1941 season and therefore intruded themselves on the attention of fishermen, and it is likely also that they extended further south than is usual.

As has been explained in Pamphlet No. 104, records of previous visitations are confused by the fact that this species has not been distinguished from the southern bluefin (*Thunnus maccoyii*). However, we now know that, as a rule, the small runs of southern bluefin disappear from the area north of Cape Howe by the end of the year and do not return until June or July. Reports of "southern bluefin" in the late summer and early winter, therefore, may be suspected as being the northern tuna, particularly (as will be enlarged on later) if mention has been made of their disinclination to take the hook.

Referring to the Merimbula occurrence, the local fisheries inspector, Mr. W. L. Packenham, reported that "from information obtained from local fishermen this appears to be only the third time these fish have been captured in these waters. In April, 1930, very extensive schools were in Merimbula bay for about three weeks. In April, 1935, small schools travelled the beaches of Eden and Merimbula for about one week." In his weekly report on pelagic fishes, dated March 9, 1940, Mr. Packenham stated that "ocean fishermen report having passed through several small patches of tuna; the fish are fairly scattered and will not take the jigs." These would probably be northern tuna, though evidently not recognized as such at the time.

At Port Hacking fishermen consider that the species appears in the area every year, but state that "they have never been so numerous" as in March–April, 1941. During this period officers of the Marine Biological Laboratory* received several reports of "yellowfin tuna" being in the port, and a large school of about 500 was said to have cruised in the vicinity of the laboratory on March 22. Several unsuccessful attempts were made to capture specimens with trolling gear, but the small school eventually caught on April 3 was taken with a beach seine. Other reports were received of shoals at Middle Harbour, Port Jackson.

Records of the species being caught by game fishermen at Port Jackson are not unusual, but further north the species seems to be more abundant. It is reported as a regular visitor in the Port Stephens area from January to May.

Fishing Results.

Attention has already been drawn to the fact that the M.V. *Warreen* on her various cruises up and down the east coast has never taken the species on her trolling lines, and moreover, during the autumn of 1941 when the several catches were being made in New South Wales with beach seines, the *Warreen* failed to obtain a strike on her jigs.

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* Laboratory of the Division of Fisheries, Cronulla.

Inquiries were made of fishermen and various big-game anglers who have had experience with the species, and the consensus of opinion was that the northern tuna was notable among local tuna species in being shy of trolled lures or jigs, but that there were occasions when it could be caught by this method. Its habit of feeding in bays and along beaches in small and large schools lent itself to capture by beach seines.

Our experience with Port Hacking shoals was that a boat trolling jigs could pass over the fish repeatedly without either scaring them or exciting them to strike. The shoals moved slowly over the shallows and were recognizable as dark patches in the water. The individual fish were not seen to breach or leap out of the water and caused no rippling or disturbance of the surface. The stomachs of those which were netted were gorged with 5- to 8-in. pilchards. The gear used was a hauling net 85 fathoms long, with 2½-in. bunt mesh and 3-in. wing mesh. An entire school of 29 fish was surrounded and three escaped just before capture. There was a short spectacular flurry when the tuna were crowded into the bunt, but they died quickly and were easily and rapidly landed, no damage being done to the net.

The Jervis Bay catch was made from a school of about 140 fish, of which 132 were taken, the seine being a jewfish (*Sciaena antarctica*) net with a bunt mesh of 4 inches, wing mesh of 6 inches and a length of 87½ fathoms. About half an hour afterwards another school was seen, but owing to the uncertainty of a sale no attempt was made at a catch. The locality was the Hole in the Wall, on the south side of Jervis Bay.

The Merimbula catch, according to a report by Mr. Packenham, the fisheries inspector, was made with a salmon net (114 fathoms of 2½-in., 24-ply seine) backed up with a second net, of 100 fathoms length and 10 by 12 bunt. "The fish punched the first net fairly easily, but it retained about one-third of them. This net took most of the fight out of the fish and the second and stronger net stopped all the fish, only one escaping under the lead line." The catch of 91 fish was made in two shots of the gear.

The following were the quantities of fish caught during the season, according to the reports received. It should be understood that the catches were purely speculative on the part of the fishermen, as there was no guarantee that the catch could be sold; therefore there was no effort at continuing the fishing.

Locality.	Date.	Catch.		Number of Hauls with Beach Seine.
		Number.	Weight.	
			lb.	
Jervis Bay	March 18 ..	132	2,948	1
Merimbula	March 21 ..	91	2,290	2
Port Hacking	April 3 ..	26	685	1
Bateman's Bay ..	May 9 ..	10	250	1
Total	.. ..	259	6,173	5

At current rates at canneries (£25 per ton) these catches would have been worth £69 to the fishermen.

The following statements from two experienced big-game anglers corroborate the previous evidence and indicate some variation of behaviour in this species of tuna.

Mr. A. F. D'Ombrain, of West Maitland, who fishes for marlin and other game fishes from Port Stephens, writes in reply to a request: —"I have gone into the matter of the northern bluefin (*Kishinoella*) and from experience gained during the past ten years I must confess that the balance of evidence favours the theory that this fish is a comparatively shy species when fished for with lures. That it will take a lure readily is beyond all doubt, but it seems to do so only at certain times. When the fish are in Port Stephens Bay they can be seen racing about in more or less large schools, feeding on garfish and other small school fish. At this stage you can follow them all over the bay, sail through and through them, and use any kind of lure or fresh bait you like without getting a strike.

"When they break up into small batches and go hunting in ones and twos I have found it a totally different proposition. At such times it is quite common to see them in the vicinity of the Nelson's Bay wharf and near the mooring of the launches, darting about after any small fish. This is the time they can easily be taken with a white feather lure or a small yellowtail, or mado, for bait. Time without number the handliners on this wharf have tried conclusions with these fish, generally using mado for bait, but, of course, have rarely been able to stop one. Specimens have been caught, but mostly they are left well and truly alone. At this time also they are often observed chasing their food up along Shoal Bay, swimming within a few feet of the shore. At low tide they seem to make out through the Heads, and it is at this time that we have had most success with the artificial lures."

In a letter received from Mr. Fred Z. Eager, of Brisbane, dated May 18, 1941, he states: "I spent this morning fishing outside Mooloolaba, and trolled two feather lures every time we moved. I suppose this might represent about 15 miles in all. We landed one tuna which measured 34⅜ inches, weighed a touch under 20 lb., had twenty gill rakers and also had a light brown liver, making the identification as a northern tuna unmistakeable. One other struck but was not landed. As we usually find, these fish were not inclined to strike the feather lures freely. Just a little south of Point Cartwright we ran through, and circled on, thick shoals of them before we made the one catch. They were feeding on the schools of small fish which we here have always called pilchards. Although we have seen these large schools for some years we have only caught a quantity of fish rapidly on two occasions. I have always believed that this was because on those occasions we were using lures which happened to resemble the fish on which the tuna were feeding. The American method of burleying them up with live bait might work, if we could do it. But the purse net sounds a certainty as these fish seem to take no notice of the boat passing through. The fish seem to be here in quantities through April and May. I got my first this year on March 29."

In June and July, 1941, the M.V. *Pasadena II.* was engaged in a fishing survey in Queensland coastal waters as far north as the Capricorn Group, attention being given to tuna trolling. During 29 fishing days only three northern tuna were trolled, but both the owner, Mr. Hugh Ward, and the Council's observer on the vessel,

Mr. I. Munro, agreed that the habits of the species were suited to commercial fishing by heavy beach seines. Mr. Munro reported:—"Hervey Bay, particularly the southern end, was the only locality where we observed tuna in any quantity working in schools in reasonably shallow water. . . . The beaches along the Hervey Bay side of Frazer Island seem to hold some possibilities for the use of beach seines for the capture of tuna and doubtless would be exploited by the local net fishermen. In the tuna season a lampara net might be used with some degree of success, but it seems that the water is too shallow, and the run of tide too great, for the use of a purse seine." A lampara net would be too light for this species; a ring net might be found more serviceable. It is likely, also, that shore traps would be very suitable gear for a fish with such habits.

Fishing experiences in Western Australia for this species present, in part, rather a different story. Though reports have been received that at certain times the tuna will not take the hook, specimens are frequently taken by trolling. As already mentioned in Pamphlet No. 104 (p. 38) many tons were caught with handlines between June and October, 1938, by the factory whaling ship *Frango* in Sharks Bay. The Western Australian evidence, fragmentary as it is, is set out in the following memorandum, prepared by Mr. John Gregory, who was temporary field officer for the Division of Fisheries in Western Australia in 1939-40:—

"Western Australian experience seems to agree in general with that of Mr. D'Ombrain—that the northern tuna at times is an aggravatingly shy species towards the lure, though there is plenty of evidence that at other times the fish will bite freely, even when in large schools. Further investigation is needed, however, before conclusive generalizations can be made.

"At Sharks Bay results with the lures were uncertain. One fishing party frequently towed the bone lure through large schools off Point Peron and Bellefin Point without getting a bite. Later in the winter, at the beginning of August, 1939, to be exact, the same fishermen obtained several strikes in quick succession when passing through a very large shoal, with, it was reported, 'fish leaping about them and off shore as far as the eye could see.' These men thought it would be easy to net large numbers of tuna with suitable gear when they school off the Peron and Bellefin Points. The fish appeared to favour the Peron waters in the winter and the Bellefin-South Passage waters in summer.

"Geraldton snapper fishermen sometimes catch scores of tuna on their 'albacore' lines on the passage to and from the Sharks Bay grounds and use them as snapper bait. The fish are much more numerous on some trips than others and seem to be most plentiful along Dirk Hartog Island during June. I was never given any exact information about the size of the schools. The tuna seem to be dispersed all along the breakers at Dirk Hartog and the coast for some distance north and south. One boat caught over 80 tuna in one trip along Dirk Hartog Island. It is possible that a powered vessel could double to and fro among the tuna and thus take a large number. It would hardly be practicable to use a net close inshore on the open coast.

"One Geraldton fisherman who fishes the Abrolhos Island waters the year round for 'albacore' (i.e., Spanish mackerel) reported somewhat similar conditions in that area. He said that great schools of tuna appear at the Abrolhos about May. For a month or so after they appear they will not take a lure, but thereafter they become a nuisance, as he cannot throw out a lure in their vicinity without hooking one. He said he could take tons of them with spinners.

"Perth big-game fishermen knew very little about the habits of the species. One angler reported passing through a solid mile of tuna some miles off Rottnest. Most of the tuna hooked were from very small schools, I believe. Information is very scanty about tuna in the waters between Fremantle and Geraldton. In fact, the whole Western Australian data are very sketchy and incomplete."

There are reports that in Western Australia the species shares the habit of the eastern fish in frequenting sheltered beaches, thus enabling them to be caught by shore-nets. Fisheries Inspector A. K. Melsom thus reports on August 21, 1940:—"On August 13, fishermen who were hauling a 2½-in. mesh fishing net for bait, off the mole at the Naval Base, Cockburn Sound, caught in their net 22 bluefin tunny. Four which were sent to Perth averaged 51½ lb. each; the heaviest weighed 57 lb."

An Investigation of the Port Hacking Sample.

Through the courtesy of the fishermen who caught them (Messrs. T. Bell and A. Maguire) 25 of the fish caught at Port Hacking on April 3 were fairly completely examined and, as they may be taken as a representative sample of the stocks which may be commercially caught in New South Wales waters during the present known fishing season (January to May), the results may be of interest.

Each of the fish was measured and the viscera from the whole catch was preserved for stomach content examination and oil analysis. A sample of the fish was canned in the Laboratory's experimental plant.

Size.—The mean length was 93·5 cm. and the mean weight 26·4 lb. in the round. The gutted weight averaged 92 per cent. of the round weight. The mean weight of the Jervis Bay catch was 22 lb. and of the Merimbula fish 25 lb.

Sex and Maturity.—There were 17 males and 8 females in the sample examined, and all were spent adult fish.

Stomach Contents.—The shoal had been feeding principally on pilchards 5 to 7½ inches in total length, averaging 9 pilchards per stomach. The average weight of food per stomach was 268 gm. (9½ oz.). Altogether the 25 stomachs contained 234 pilchards, 2 scad, 2 mackerel, 1 leatherjacket, 1 other fish, and 1 squid.

Other local stomach content records are as follows:—

Mr. G. P. Whitley identified the following from a 50-lb. tuna caught at Port Stephens on February 26, 1935:—"The post-larvae of a species of shore-crab and a little boxfish, the young of *Ostracion diaphanum*, which is by no means commonly caught in New South Wales. It is more tropical in its range, but probably young examples drift southward on the notonectian current at about this time of the year. A lot of small leatherjackets were also in the stomach."

A specimen from Lindeman Island, Queensland, July 11, 1939, had a long tom, *Tylosurus terebra,* 23 cm. long, and two garfish, 48 cm. long. Another fish from the same area examined by Mr. Whitley on August 1, 1935, contained the "pen" of a squid (*Sepioteuthis*) and fish remains.

Specimens caught at Hervey Bay, Queensland, by the M.V. *Pasadena* on June 24, 1941, contained anchovies (*Engraulis australis*).

Examples from Western Australia contained anchovies (*Engraulis australis*) (Dirk Hartog Island, July 16, 1938) and a herring (*Harengula punctata*) (Bernier Island, July 9, 1938).

The clupeoids mentioned were identified by Mr. M. Blackburn.

Weight and Oil Content of Viscera.—The various portions of the viscera were separately treated, and the results were as follows (oil analyses by C. C. Kuchel):—

Organ.	Mean Weight. gm.	Percentage Oil in Pooled Sample. %
Milt	49·3	1·66
Roe	103·0	1·00
Liver	113·5	5·86
Pyloric caeca	211·6	(*a*) 12·12 (*b*) 13·10
Stomach	188·4	1·40
Intestines	38·2	3·03
Spleen	52·0	1·00

The total weight of viscera, or gut, in the 25 fish was 37 lb., exclusive of the weight of the stomach contents. The computed oil content for the whole, allowing for the proportion of the sexes, was 7·5 per cent.

Canning Test.—Mr. E. J. Ferguson Wood reports as follows:—

"Nine specimens of the northern tuna (*Kishinoella tonggol*) have been canned at this laboratory, and, although the number is still small, it suffices to show that a delicious canned product results. The pre-cooking time is much shorter than for southern bluefin of equal weight owing to the thinner body of the fish and consequent more rapid heat penetration. The average yield of canned fish was 27·9 per cent. of the original round weight, and weight losses were very uniform. This is a rather lower yield than for southern bluefin, owing to the thinner shape of fish and increased ratio of bone, &c., to white flesh.

"The flavour of this fish is rather richer than that of southern bluefin and approaches nearer to that of striped tuna. If northern tuna can be caught in commercial quantities it has great possibilities as a canned fish.

"Pre-cooking times of fish of an average weight of 24 lb. 3 oz. were between 60 and 120 minutes, and all packed between these times were quite successful. The fish were packed in cottonseed oil with the salt added and retorted at 240°F. for 75 minutes, so that the cans were strictly comparable with cans of southern bluefin."

The Tuna *Kishinoella tonggol* Bleeker in Australia.

*By D. L. Serventy, B.Sc., Ph.D.**

Summary.

It is shown that, under the name of *Thunnus maccoyii* Castelnau, two distinct tuna species have been confused in Australia in the past. One of these, of which a detailed taxonomic description is given in the present paper, is demonstrated to be specifically identical with *Thynnus tonggol* Bleeker, described from Java in 1852, but regarded as of uncertain status by recent reviewers. Later synonyms are *Thunnus rarus* Kishinouye (from Japan) and *Thunnus nicolsoni* Whitley (Queensland). The species, which is placed generically in *Kishinoella*, closely allied to *Neothunnus*, appears to be a common and widespread Indo-Malayan form.

1. Introduction.

For many years past zoologists have considered that the common Australian tuna, *Thunnus maccoyii* Castelnau, and close ally of the European *T. thynnus*, had a very wide distribution in local waters, ranging far to the north on both the western and eastern coasts. During the recent investigations on the tuna fishes for the Council for Scientific and Industrial Research, it became clear that two distinct, though superficially rather similar, species were being confused. The southern tuna or bluefin, *Thunnus maccoyii*, was found to be confined to the southern coastline, from Sydney southwards on the east, and to the east and south of Cape Leeuwin, in Western Australia. North of these limits occurred a species which is common in the Indo-Malayan region and is known in the current literature as *Neothunnus rarus* Kishinouye, but was unrecorded as such in Australia. Jordan and Evermann (1926) have placed the species in a separate genus, *Kishinoella*, and I will presently show that the specific name must also be altered as the species seems identical with the long-lost "*Thynnus tonggol*" described by Bleeker from Java in 1852. I find also that *Thunnus nicolsoni*, described as new by G. P. Whitley from the Great Barrier Reefs, Queensland, in 1936, and unrecorded since that time, is the same form. Though, apart from the last-mentioned record, the species has never been reported from Australian seas under any of the preceding names, there are many references both in scientific and popular literature to the southern tuna (*T. maccoyii*) which really appertain to this northern form.

From what we now know, the records of *T. maccoyii* from Queensland waters by Ogilby (1908, 1912), and McCulloch and Whitley (1925) among other lesser references, must refer to *Kishinoella tonggol*, whilst there exist numerous photographs in the popular press of anglers' catches illustrating the same species, but the captions either directly or by implication refer to it as the southern tuna.

It is curious that so acute an ichthyologist as the late A. R. McCulloch was unaware that under the name *Thunnus maccoyii* he was confounding two species. For very many years there was exhibited a specimen of *Kishinoella tonggol* in the fish gallery of the Australian Museum, Sydney, labelled as *Thunnus maccoyii*. When examining the

* An officer of the Division of Fisheries.

manuscript and photographic records of the Australian Museum, however, Mr. Whitley and I were astonished to discover an old photograph of a tuna, dating possibly from the days of J. Douglas Ogilby, and labelled in an unknown hand: "*Orcynus tonggol.*" The specific identification is correct, but whether it was purely fortuitous or an instance of someone's rare insight, which unfortunately never reached the publication stage, will probably now never be revealed.

Attention was first directed to the subject when in April, 1939, this Laboratory received from Mr. John Gregory, of Perth, a tuna caught by Mr. Frank Boan off Rottnest Island on 26th March. The specimen was assumed to be a southern tuna and externally it was not unlike, though the much more slender body indicated a difference from other populations examined. Dissection showed, however, that it was no southern tuna, but a member of a wholly different genus.

Since then I have examined 40 specimens, including an example from Lindeman Island, Queensland—the type locality of Whitley's *nicolsoni*. In addition, Messrs. L. Glauert and J. Gregory, of Perth, have furnished me with particulars of eight additional specimens, and Mr. I. Munro of nine from Queensland. Examination and measurements were made of fish thawed out after having been frozen for various periods and also of fresh material. A typical specimen is shown in Plate 4, Fig. 1.

2. Distribution.

Identified specimens have been taken at the following localities:—*Western Australia:* near Onslow; Red Bluff, near Cape Cuvier; Koks Island; Quoin Head and Cape Inscription, Dirk Hartog Island; Broadhurst Bight, Peron Peninsula; Rottnest Island, near Fremantle. *Eastern Australia:* Lindeman Island, Whitsunday Group; Fitzroy Reefs; Port Hacking and Jervis Bay. Records based on photographs and other data are:—*Western Australia:* Naval Base, Cockburn Sound; Fremantle harbour. *Eastern Australia:* Port Stephens; Broken Bay; Sydney; Cronulla; Wollongong; Jervis Bay; Bateman's Bay; and Merimbula. Thus the present known southern limits are Fremantle (Lat. 32° S.) on the west and Merimbula (Lat. 37° S.) on the east.

3. Description.

From the accumulated data the following features appear to characterize the Australian populations of *Kishinoella tonggol*:—

(*a*) *Size.*

The specimens examined have weighed between 11 and 42 lb., all being adult fish. The lengths varied from 71 to 115 cm. A graph showing length-weight relationships has already been published (Serventy, 1941). Larger specimens, weighing up to 60 lb., have been reported by fishermen. Kishinouye (1923) states that in Japan 13 lb. is regarded as the average weight, 26 lb. being considered as the maximum.

(*b*) *Colour.*

Compared with other tunas this species has in general a drab coloration. The back varies from dark greenish-grey to bluish-black, passing to silvery-grey below. On the lower sides of the body, below

the level of the pectoral fin, and extending a variable distance posteriorly, is an area of white spots or blotches disposed in horizontal lines. A narrow purplish line runs from the caudal keel for a variable distance anteriorly. It seems to be an evanescent feature, soon disappearing after death. In the first dorsal fin, the spines are pale, the web grey with an olive tint near the margin. The second dorsal is dark grey with olive along the hinder margin. The caudal fin is dark grey with olive medially. The anal fin is paler grey with slight olive on the hinder margin. The pectoral fin is dark grey, with black on the inner surface. The dorsal and ventral finlets are yellow with grey margins. The caudal keels are grey. The inside of the mouth is whitish flesh.

(*c*) *Fin Formulae.*

The *first dorsal fin* consists usually of 13 spines. The following is the frequency distribution for 46 specimens, examined for this character:—

Number of spines	11	12	13	14
Individuals	1	2	42	1

The *second dorsal fin* has usually 14 rays followed by 9 finlets. As this and the anal fins are thick and fleshy the skin must be scraped off to expose the rays clearly enough for counting, and in some instances it may be necessary to treat the fin with a caustic solution. Out of 17 fish on which counts were made 15 had 14 rays and two had 15. One of these latter was followed by only eight finlets. The total of rays and finlets appears fairly constantly to be 23; 16 fish had 23 and one 24.

In the *anal fin* there are usually 14 rays, followed by 8 finlets. Fourteen specimens had 14 rays and three had 13. One of the latter was followed by 9 anal finlets. The total of rays and finlets together was 22 in fifteen cases and 21 in two.

The most anterior *finlet* in both dorsal and ventral series is not infrequently adnate to the second dorsal and anal fins, respectively, and as the posterior dorsal and anal rays approach the finlets in form and size it is sometimes difficult to draw the line between them. The finlet series may be regarded as disconnected portions of primitively continuous second dorsal and anal fins and, therefore, the sum of ray and finlet numbers should give a less variable value than the two considered separately. Frade (1931) has found this to be so with *Thunnus thynnus* in Europe and I have established the same with large series of the related *Thunnus maccoyii*. The sample of *K. tonggol* studied is small, but the data point in the same direction. Where the main fin shows less than the usual number of rays there is a compensating increase in finlet number. In practice the finlet counts are of little utility if the rays in the second dorsal and anal fins have not been determined.

The rays in the *pectoral fin* give the following frequencies:—

Number of rays ..	31	32	33	34	35
Individuals	3	7	9	9	2

The *fin formula* is, therefore: D, 11–14, 14–15, 8–9; A, 13–14, 8–9; P, 31–35, the most usual being D, 13, 14, 9; A, 14, 8; P, 32–34. This compares with the following generalized formula for *Thunnus maccoyii*: D, 13 or 14, 15, 8 or 9; A, 14, 8; P, 32 (30 to 34). Thus with only

a few specimens available for examination it is inadvisable to depend on fin ray counts as the sole means of distinguishing between the two species.

The *scale row* for eighteen examples has a mean value of 219·4 with a standard deviation of 8·8. The observed range was between 200 and 231, and only two counts fell below 210.

The *gill raker* frequencies are given below for the dorsal and ventral limbs and the aggregate number in the first gill arch:—

Dorsal limb.—Number of rakers:	5	6	7	8	
Individuals:	4	15	5	2	
Ventral limb.—Number of rakers:	14	15	16	17	
Individuals:	1	9	12	4	
Total.—Number of rakers:	20	21	22	23	24
Individuals:	4	6	7	8	2

The modal formula is, therefore, 6/16. That for *Thunnus maccoyii* is 11/22–23.

(*d*) *Body Proportions.*

In Table 1 are summarized the ratios usually employed in fish taxonomy. The original measurements were all taken with calipers and represent the direct distances between the various points of reference, no measurements being made along the curvature of the body. In this respect the method of measuring differs, for certain of the dimensions, from that used by Russell (1934) and the one recommended by the International Commission for the Exploration of the Mediterranean (1932).

The length is taken in a direct line from the apex of the upper jaw to the end of the central rays of the caudal fin. The head is measured from the snout to the furthest edge of the gill-cover and the pre-operculum similarly to its furthest edge. The length of the pectoral fin is taken with the fin fully erected and is the chordal distance from its base to the tip (measured from the point B in Fig. 7 (ii) in Russell, 1934).

The data in Table 1 require some comment. In a recent text-book (Simpson and Roe, 1939) it is stated that the coefficient of variation (the standard deviation expressed as a percentage of the mean), employed as a measure of variability in zoology, usually lies between 4 and 10. Low values point to the sample being insufficient to reveal the variability and larger ones suggest that the sample is not homogeneous. No value in Table 1 exceeds this upper limit, but nine out of the 23 ratios have a coefficient of variation below 4, indicating that a larger series would show greater variability than is disclosed by the figures given. It may be doubted, however, whether this can be stated unreservedly and it is quite likely that some of the ratios, at least, have a very low intrinsic variability. For example, in another species of tuna, *Thunnus maccoyii*, a sample of 202 fish gave, for the relationship, body length/length from snout to vent, a mean value of 1·64, a σ of 0·023, and a coefficient of variation of 1·4 per cent. It seems fairly clear, therefore, that the position of the vent in respect of the total length is remarkably constant for these fishes and hence to be accounted as an excellent specific character.

TABLE 1.

Ratio.	Number of Specimens.	Observed Range.		Mean.	σ	Coefficient of Variation. %
		Minimum.	Maximum.			
Head length/eye diameter	29	6·86	9·84	8·57	0·691	8·6
Head length/inter-orbital ..	25	2·59	3·05	2·79	0·117	4·2
Body length/head length ..	29	3·74	4·01	3·87	0·076	2·0
Body length/snout to origin of first dorsal fin ..	25	3·45	3·80	3·69	0·087	2·4
Body length/snout to origin of second dorsal fin ..	25	1·95	2·11	2·00	0·037	1·8
Body length/snout to origin of ventral fin	25	3·27	3·56	3·47	0·071	2·0
Body length/snout to vent	24	1·77	1·86	1·82	0·027	1·5
Body depth at first dorsal origin/inter-axillary diameter	20	1·35	1·58	1·43	0·064	4·5
Head length/maxillary length	21	2·66	2·84	2·74	0·047	1·7
Head length / pre-opercular length	22	1·23	1·32	1·28	0·024	1·9
First dorsal fin, percentage of body length	26	10·3	12·9	11·3	0·553	4·9
Second dorsal fin, percentage of body length	26	12·2	15·0	13·5	0·747	5·5
Anal fin, percentage of body length	25	12·6	15·7	13·9	0·800	5·7
Upper caudal lobe, percentage of body	20	14·8	18·2	16·4	0·836	5·1
Body length/depth at vent	25	4·9	5·8	5·19	0·228	4·4
Body length/pectoral length—						
Western Australia ..	10	4·8	6·2	5·46	0·412	7·5
Eastern Australia ..	16	5·6	6·4	6·00	0·280	4·7
Head length/pectoral length—						
Western Australia ..	10	1·27	1·57	1·41	0·092	6·5
Eastern Australia ..	16	1·41	1·69	1·55	0·072	4·7
Body length/greatest depth—						
Western Australia ..	8	4·38	4·62	4·48	0·074	1·7
Eastern Australia ..	19	4·12	4·63	4·30	0·141	3·3
Body depth at origin of first dorsal fin/depth at vent—						
Western Australia ..	10	1·04	1·23	1·11	0·056	5·0
Eastern Australia ..	14	1·04	1·26	1·16	0·052	4·5

For four of the ratios, differences were found between the mean values for Western Australian and Eastern Australian samples, indicating a racial differentiation between them. The differences concern the relative length of the pectoral fin and the degree of plumpness of the body. Western Australian fish have relatively longer fins and more slender bodies than fish in Eastern Australia, but the overlap is too great to warrant the use of these characters for the taxonomic separation of the two groups even subspecifically. The differences between the means are statistically significant when the t test is applied (for ratio body length pectoral length, $t = 3{\cdot}99$; head length pectoral length, $t = 4{\cdot}34$; body length greatest depth, $t = 3{\cdot}39$; body depth at origin of first dorsal fin depth at vent, $t = 2{\cdot}28$; the differences are significant in the case of the first three ratios and possibly so in the last one).

There is a possibility, suggested by similar work on *Thunnus maccoyii* (Serventy, unpublished), that the differences may really be due to differential (allometric) growth. To circumvent difficulties of this nature, comparison should have been made between samples of similar-sized fish. Unfortunately this was not possible; the mean length of the Western Australian sample was 85·1 cm. whilst that of the Eastern Australian was 93·0 cm.

(e) Other Relationships.

The size of the *pectoral fin* is better appreciated, perhaps, when given as the length when pressed along the body, though it is not so accurately measured in this way. On this basis the pectoral in Western Australian fish averages 21 per cent. of the body length and that in Eastern Australian 18 per cent. The fin usually reaches to the level of the second-last spine of the first dorsal fin, but may fall slightly short of this (to between the second and third last) or may reach as far as the middle of the interval between the two dorsal fins. Its tip falls far short of the level of the vent.

The position of the *greatest girth* falls between the seventh and tenth spines of the first dorsal fin.

In Table 2 are given the original measurements (in cm.) and other details of a specimen from Rottnest Island, Western Australia, of which a cast has been made, copies being held at the Australian Museum, Sydney, and the Marine Biological Laboratory, Cronulla. The specimen was collected in March, 1939.

TABLE 2.

Sex	Male
Weight	25¼ lb.
Lengths in cm.—	
Total length	91·7
Diameter of eye	2·9
Head length	23·7
Snout to origin of pectoral	23·7
Snout to origin of first dorsal	25·3
Snout to origin of second dorsal	46·5
Snout to origin of ventral	27·0
Snout to vent	51·8
Height of body at origin of first dorsal	20·8
Length of pectoral	15·4
Inter-orbital diameter	8·4
Height of body at vent	18·6
Inter-axillary diameter	13·7
Length of maxillary	8·7
Length of pre-opercular	18·8
Height of first dorsal	10·0
Height of second dorsal	11·9
Height of anal	13·0
Height of upper caudal lobe	14·3
Base of pectoral	5·0
Vertebrae	39
Scale row	c. 216
Gill rakers	6/16
Fin ray counts—	
Dorsal fins	13, 14, 9
Ventral fins	13, 9
Pectoral	34

(f) Internal Anatomy.

There is no *swim-bladder.*

The *liver* (Fig. 1) is a pale-brown organ, divided into three lobes, with the right lobe narrower and longer than the others. The margins are rounded and there are no secondary lobules as in *Thunnus.* There are no venules on the external surface. These characteristics make the liver a useful means of readily distinguishing this species in the field from *Thunnus maccoyii* (Serventy, 1941, Fig. 9).

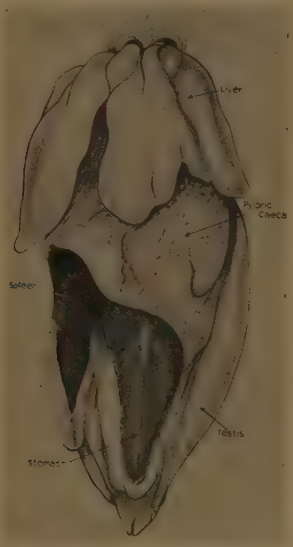

FIG. 1.—Viscera of *Kishinoella tonggol.*

The arrangement of the primary transverse branches of the veins and arteries of the *subcutaneous system,* as shown by a study of serial sections, is similar to the condition described by Kishinouye (1923), in his account of Japanese examples. The branching arteries of the subcutaneous system are given off in two rows from the longitudinal trunk of the subcutaneous artery, from the side of the vessel facing the mass of the dark tissue. Each branch alternates with its fellow. There is only one row of veins joining the longitudinal vessel and disposed on the same side as the arteries. The segmental series of arteries and veins are given off on the opposite side to that of the subcutaneous vessels.

The *skeleton* shows similarity in all details with Kishinouye's illustrations of the Japanese form. All, of twelve examples studied, possessed 39 vertebrae, and in each case the closure of the haemal arch occurred on the eleventh vertebra. Details of the cranium are illustrated in Plate 5 and Plate 4, Fig. 2.

4. Comparison with other Descriptions.

(*a*) With *Thunnus nicolsoni* Whitley, 1936; Lindeman Is., Queensland.

The body proportions given by Whitley, where they can be compared, fall within the range of variation given in Table 1. There is agreement also in the fin ray formulae, excepting for P, which is given as 36, compared with my observed limits of 32-34. The gill raker count agrees.

(*b*) With *Neothunnus rarus* Kishinouye (as described in 1923): Japan.

The colour pattern, fin formulae, gill-rakers, scale row, absence of swim-bladder, disposition of subcutaneous blood-vessels and skeletal features, are in agreement with my material. Kishinouye has not given any body proportions, but the ratios as worked out from his drawing in Plate xxvii, together with the relative sizes of the fins, all fall within my range of variation, excepting the ratio of body length/greatest depth. The ratio for Kishinouye's fish is 3·79, outside of my limits and indicating a somewhat less slender fish. If the figure is correctly drawn in this respect it may mean a racial difference is involved.

(*c*) With *Thynnus tonggol* Bleeker, 1852: Batavia.

As this, the first description of the species, occurs in a publication not readily accessible, and has been consistently overlooked by later workers, it may be quoted in its original form:—

"Thynn. corpore subelongato compresso, altitudine 5 fere in ejus longitudine, latitudine 1 2/5 circiter in ejus altitudine; capite acuto 4 et paulo in longitudine corporis, multo longiore quam alto; linea frontali leviter convexa; oculis diametro 4½ in longitudine capitis; rostro acuto oculo longiore; rictu ante oculos desinente; maxillis dentibus mediocribus utroque latere p.m. 32; praeoperculo limbo posteriore emarginato; margine operculari membranacea non fimbriata; vesica natatoria nulla; linea laterali antice valde flexuosa poris magnis incipiente postice declivi serpentina; cataphracta pinnas dorsalem radiosam et analem amplectente, lateribus sub linea laterali post apicem pinnarum pectoralium desinente, utroque latere incisuris 2 magnis, incisura inferiore post insertionem pinnarum ventralium desinente; pinnis dorsalibus altitudine aequalibus, corpore duplo circiter humilioribus, non contiguis, distantia interpinnali pinna radiosa plus triplo breviore; pectoralibus 1 1/5 in longitudine capitis; ventralibus capite plus duplo brevioribus; anali post dorsalem radiosam inserta; caudali profunde emarginata lobis acutis 5½ in longitudine corporis; colore corpore superne profunde coeruleo inferne griseo-argenteo; dorso maculis vel fasciis nullis; pinnis griseo-plumbeis vel fuscescente-plumbeis; pinnis spuriis singulis antice flavis postice ngris.

B. 7. D. 13-2/12 + 8 spur. P. 2/27. V. 1/5. A. 3/10 + 8 spur. C. 21 et lat. brev.

Synon.—*Ikan Tonggol* Mal. Batav.

Habit.—Batavia, in mari.

Longitudo speciminis uncini 650.'"

With one outstanding exception (that of the relative size of the eye), Bleeker's general description fits the Australian examples very well. The length/body-height ratio ("almost 5") is of the other extreme to that in Kishinouye's illustration of *rarus*, and indicates a more slender fish than the Australian, but the ratio is near our range. (It will be recalled that the specimens of Western Australian fish examined were found to be more slender than the Eastern Australian.) There is particular mention of the absence of a swim-bladder.

As to the one prominent discrepancy, Bleeker states: "oculis diametro 4½ in longitudine capitis." This represents about double the

diameter of the eye in our Australian samples, and a huge eye of this magnitude, had it really occurred, would assuredly have been specially remarked on by the author. I wrote to Dr. F. P. Koumans, of the Rijksmuseum van Natuurlijke Historie, Leiden, on the chance that some of Bleeker's material or data might still be extant, and received word that two specimens of Bleeker's collection of *Thynnus tonggol* were preserved there, one of which was the type. Dr. Koumans informed me that Bleeker had related the eye diameter not to the length of head as now understood, but to the distance between the snout and the upper end of the gill cover. In this way the eye was contained four and a half times in the head. Taking the head as the distance to the margin of the operculum, the eye ratio was "about six times." This falls near the limits of variation of our Australian specimens.

Dr. Koumans was kind enough to supply further details of the specimens, including a photograph, adding his concurrence with the view that the three species, *tonggol*, *rara*, and *nicolsoni*, were identical. The most important of the additional information is the gill-raker formula which had been omitted by Bleeker. Dr. Koumans said that in both specimens the formula was about 5/15–17 on the first gill arch, a number corresponding with the Australian forms and with *rara*.

There are some discrepancies between Dr. Koumans's particulars and the original description of Bleeker. Thus Bleeker recorded the length as 650 mm. Dr. Koumans gives the lengths of the two specimens as 700 mm. (this one is presumably the type) and 500 mm. By comparison with the rule included in the photograph (Plate 3) I have calculated them to be 747 and 503 mm. respectively, from the snout to the caudal bifurcation. These variations may be due, however, to distortions of the specimen under preservation and the consequent difficulties of measuring. For the fin formulae Dr. Koumans gives: D, 12, 14, 9; A, 12, 9; P, about 34; compared with the following given by Bleeker: D, 13, 14, 8; A, 13, 8; P, 29. Unfortunately the course of the war has interrupted further correspondence on the subject.

(*d*) With *Kishinoella zacalles* Jordan and Evermann, 1926; Hawaii.

Kishinoella zacalles is the only other member of the genus and differs markedly from *K. tonggol* in its plumper body (length/body height ratio: 3·66) with a longer pectoral fin (about 25 per cent. of the body length when pressed against the body, and reaching beyond the level of the vent to the first dorsal finlet). There are more gill-rakers (9/21) and the colour markings are different (in the form of transverse streaks instead of horizontal rows of spots).

5. General.

Bleeker described *tonggol* in 1852, the reference being cited by Gunther in his Catalogue of Fishes in the British Museum with a brief but inadequate summary of the original description. Almost all subsequent authors, including Jordan and Evermann (1926), in their review of the tunnies, seem to have gone no further than Gunther in their search of the literature concerning this species. There is no doubt that the omission by Gunther of such a key character as the absence of a swim-bladder has been responsible for the non-recognition of *tonggol* by later workers, including Kishinouye, who believed that his *rara* was the only tunny to lack a swim-bladder. Of *tonggol*,

Jordan and Evermann wrote: "This species is known to us by Bleeker's record only. The species seems to differ from *Thunnus thynnus,* mainly in the slenderer form and especially in the longer pectoral which is said to equal depth of body," and they proceed to paraphrase Gunther's summary of characters, not Bleeker's original description, though, curiously, they cite the latter as their only reference.

The absence of a swim-bladder and the low number of gill-rakers, revealed by the re-examination of the type by Dr. Koumans, are the two decisive features identifying *tonggol* with the Australian fish and the Japanese *rara,* and they are supported by several other characters as elaborated in the preceding discussions.

The species "*Thynnus tonggol*" is mentioned in the literature on a few occasions. Duncker (1904) includes it without commentary in a species list of fishes from Singapore. In the belated account of the fishes collected by the *Magenta* in 1865-68, Tortonese (1939) quotes Giglioli, one of the zoologists of the expedition, as reporting this species in abundance in the Java Sea, some being caught between Sumatra and Borneo. Tortonese remarks that the species is "still obscure and unknown except for the observations of Bleeker." That he was unaware of its affinities with Kishinouye's *rara* is indicated on p. 317 of his report where, in discussing tunnies generally, he says: "The swim-bladder is lacking in one species alone (*Thunnus rarus* Kish. of Japan)." Giglioli's reference suggests that at that time the name *tonggol* was current for the species but since then had passed into desuetude.

Since *rara* was described in 1913, it has been reported from a wide area in the Orient, even though it appears to be a scarce form in Japan and occurring in southern waters only. Deraniyagala (1933) states that it is "not uncommon along the south coast of Ceylon during November and December," and gives the Maldive Islands as an additional locality. Delsman and Hardenberg (1934) consider a tunny, which they identify "at least for the time being" as *rara,* to be abundant in Javanese seas.

In brief we may say that the species is a wide-spread and probably common Indo-Malayan form, extending to southern Japan in the north and to about Lat. 37° S. in Australian waters. It occurs at least as far west in the northern Indian Ocean as the Maldive Islands, and there are no data as to its eastern limits. An allied species (*Kishinoella zacalles*) appears to replace it in the waters about the Hawaiian Islands.

6. Synonymy.

The following synonymy contains the significant references to this species or what I consider probably refer to it:—

Thynnus tonggol Bleeker, *Nat. Tijdschr. Ned. Ind.,* **1**: 356 (1852), Batavia.

Thynnus tonggol Bleeker, *Verh. Bat. Gen.,* **24**: 89 (1852).

Thynnus tonggol Gunther, *Cat. Fish. Brit. Mus.,* **2**: 364 (1860).

Thynnus tonggol Bleeker, *Versl. Akad. Amsterdam,* **12**: 52 (1861) (*vide* Corwin).

Thynnus tonggol Bleeker, *Ned. Tijdschr. Dierkunde,* **3**: 356 (1866). (*vide* Weber and de Beaufort).

Thynnus tonggol Duncker, *Mitt. Naturhist Mus. Hamburg,* **21**: 158 (1904).
Thunnus thynnus Ogilby, *Proc. Roy. Soc. Q'ld.,* **21**: 24 (1908) (not *T. thynnus* Linn).
Thunnus thynnus Ogilby, *Mem. Q'ld. Mus.* **1**: 58 (1912).
Thunnus rarus Kishinouye, *Suisan Gakkwai Ho,* **1**: 28 (1915), Japan (*vide* Kishinouye, 1923).
Neothunnus rarus Kishinouye, *J. Coll. Agric. Imp. Univ. Tokyo,* **12**: 448 (1923).
Thunnus maccoyii McCulloch and Whitley, *Mem. Q'ld. Mus.*, **8**: 142 (1925) (not *T. maccoyii* Castelnau).
Thunnus maccoyii (part) McCulloch, *The Australian Encyclopedia,* **2**: 599 (1926).
Thunnus maccoyii (part) McCulloch, *Austr. Mus. Mem.*, **5**: 263 (1929).
Neothunnus tonggol Jordan and Evermann, *Occ. Papers Calif. Acad. Sci.,* **12**: 22 (1926).
Kishinoella rara Jordan and Evermann, *Ibid.,* p. 26.
Neothunnus rarus Deraniyagala, *Ceylon J. Sci.*, B., **18**: 49 (1933).
Thunnus (*Neothunnus*) *rarus* Delsman and Hardenberg, *De Indische Zeevisschen en Zeevisscherij* (1934), p. 336.
Thunnus nicolsoni Whitley, *Mem. Q'ld. Mus.*, **11**: 30 (1936).
Thunnus tonggol Tortonese, *Boll. Mus. Zool. Anat. Comp. Torino,* **47**: 326 (1939).
Kishinoella tonggol Serventy, Coun. Sci. Ind. Res. (Aust.), Pamph. 104 (1941), p. 33.

7. Acknowledgments.

For assistance during this investigation I am indebted to the authorities of the Australian Museum, Sydney, for access to their specimens and records, and, in particular, to the ichthyologist, Mr. G. P. Whitley; to Mr. L. Glauert, curator of the Western Australian Museum; Mr. A. J. Fraser, Chief Inspector of Fisheries, Western Australia: Mr. T. C. Roughley, Superintendent of State Fisheries, New South Wales; Mr. E. A. Cornish, Senior Biometrical Officer, Council for Scientific and Industrial Research; Mr. John Gregory, formerly of Perth; and Dr. F. P. Koumans, of Leiden, Holland. Miss Mary Soady was responsible for the finished drawing in Fig. 1.

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A Comparison of Liral Crown and Concurrent Varieties of Fibre Flax.

*By Jean F. Couchman, B.Sc., A.A.C.I.**

Summary.

Comparisons have been made between Liral Crown and Concurrent varieties of flax grown under approximately the same conditions in each of three different districts in Victoria. In every case Liral Crown was proved to be the better fibre flax, whether considering the yield, quality, or strength of the fibre produced.

1. Introduction.

At the present time both Liral Crown and Concurrent varieties of fibre flax are grown in various parts of Australia and constitute practically the only varieties cultivated on a large scale. Liral Crown, a blue flowering plant, first introduced by the Linen Industry Research Association of Northern Ireland, was brought into this country by Flax Fibres Pty. Ltd. Concurrent is a white flowering Dutch variety which was obtained from the British Government early in 1940.

Unless the present acreage of 60,000 annually is progressively increased, there will be a surplus of flax seed, and some discrimination between the varieties for sowing purposes will eventually be necessary. In anticipation of this, investigations were planned to determine the relative merits of the two varieties for the production of fibre. Information was required as to whether some districts would be more favourable to the growing of one or the other, or whether it would be advisable to concentrate on one variety only.

* An officer of the Flax Section, Division of Forest Products.

After consultation with State Agricultural Department officers, tests on a commercial rather than a laboratory scale were decided upon. For the comparisons, flax was chosen from three Victorian districts, where both varieties had been grown by the same grower, under approximately similar conditions. The districts were—

(*a*) Benalla.
(*b*) Gisborne.
(*c*) Whorouly South (near Myrtleford).

It was proposed to watch all the processing carefully, obtaining comparative figures throughout, to cover the deseeding, retting, and scutching. Subsequently it was also arranged to have the fibre graded and spun. Thus, by processing six samples of straw, consisting of Liral Crown and Concurrent from three different districts, it became possible to obtain three separate comparisons of both varieties covering a fairly wide area.

2. Experimental.

(i) *Deseeding.*

Weighed quantities of the original straw (from 5½ to 8 tons) were deseeded by a Soenens type machine. Weights of seed and chaff from each lot were obtained and then, by difference, the amounts of weed, short straw, &c., removed by the machine were estimated. These results were calculated as percentages of the original straw and are shown in Table 1.

(ii) *Retting and Scutching.*

Retting was carried out at Myrtleford, Victoria. The straw was packed vertically in concrete tanks capable of taking an average of 4¼ tons of deseeded straw. Each ret was given a wash for seven to eight hours at approximately 75°F., and retting was continued at the end of this time by refilling the tanks with fresh warm water to give a ret temperature of approximately 81°F. This temperature was raised 3° to 4°F. every twelve hours by 10 per cent. dilutions (or sprays) until it reached 95°F. If the ret was still unfinished, another 10 per cent. dilution was given, and then all subsequent dilutions were 5 per cent., the temperature being maintained as near to 95°F. as possible until the straw was retted. Ret end points were determined by the electrometric method* in conjunction with physical tests.

At the conclusion of retting, the straw was gaited until dry, and then scutched. The line fibre and tow from each lot were weighed and the fibre yields calculated. These figures are shown in Table 1.

(iii) *Grading.*

The fibre had been tied into bundles of approximately 11-lb. weight. Each bundle was handled separately by the grader and stricks were taken out for examination. Grades were A, B, C, D, and E (A lowest). At the present market value of flax—

A grade is worth £172 sterling per ton.
B grade is worth £180 sterling per ton.
C grade is worth £190 sterling per ton.
D grade is worth £200 sterling per ton.
E grade is worth £210 sterling per ton.

* Munro, A. M., and Couchman, J. F. (1939).—*J. Coun. Sci. Ind. Res.* (Aust.) 12: 191-202.

TABLE 1.—COMPARISON OF YIELDS FROM LIRAL CROWN AND CONCURRENT VARIETIES OF FLAX.

District	Benalla.		Gisborne.		Whorouly South.	
Variety	Liral Crown.	Concurrent.	Liral Crown.	Concurrent.	Liral Crown.	Concurrent.
Experimental Lot Number	1.	2.	3.	4.	5.	6.
Total deseeding loss .. .. .. %	25·0	35·4	29·6	34·4	34·7	34·9
Seed .. .. %	6·6	15·9	8·7	12·9	9·0	8·8
Chaff .. .. %	11·5	11·9	9 8	9·3	12·9	11·8
Winnower refuse .. .. .. %	..	..	2·9	2·7	1·6	..
Weed, short straw, &c. (by difference) %	6·9	7·6	8·2	9·5	11·2	14·3
Line—						
Calculated on original weight .. %	15·7	13·4	14·1	13·2	11·7	9·8
Calculated on deseeded weight .. %	20·9	20·7	20·0	20·2	17·9	15·0
Calculated on retted weight .. %	25·8	26·5	25·1	24·1	23·1	21·5
Tow—						
Calculated on original weight .. %	4·0	4·7	6·1	5·7	5·6	5·1
Calculated on deseeded weight .. %	5·4	7·3	8·7	8·7	8·5	7·9
Calculated on retted weight .. %	6·7	9·3	10·9	10·4	10·9	11·3
Line/Tow ratio	3·9/1	2·9/1	2·3/1	2·3/1	2·1/1	1·9/1
Ret loss .. .. %	18·8	21·8	20·4	16·0	22·3	30·2
Retting time .. .. Total hours	90·5	104·5	126·0	118·0	104·0	118·0
Straw length .. .. inches	34	29	34	33	38	32
Yield straw/acre .. .. cwt.	43	22	40	33	35	36
Price paid for straw per ton ..	£ s. d. 7 7 6	£ s. d. 6 15 0	£ s. d. 7 5 0	£ s. d. 7 5 0	£ s. d. 6 15 0	£ s. d. 6 17 6

The amount of each grade in each lot was weighed in order to obtain an accurate comparison of their values. In Table 2 a complete analysis of the grading is set out.

TABLE 2.—GRADING.

District	Benalla.				Gisborne.				Whorouly South.			
Variety	Liral Crown.		Concurrent.		Liral Crown.		Concurrent.		Liral Crown.		Concurrent.	
Experimental Lot Number	1.		2.		3.		4.		5.		6.	
	lb.	%	lb.	%	lb.	%	lb.	%	lb.	%	lb.	%
*Outfall	..	..	25	1·1	..	..	..	..	..	..	..	..
A	..	..	704	30·9	..	..	39	2·3	..	..	41	2·7
B	..	..	1,081	47·5	..	..	202	12·1	28	1·8	201	13·4
C	404	20·3	467	20·5	181	10·7	1,194	71·8	105	6·7	896	59·5
D	1,157	58·3	..	..	958	56·4	229	13·8	1,039	66·3	367	24·4
E	424	21·4	..	..	558·5	32·9	..	..	394	25·2	..	..
Value—£ per ton sterling	200·1		179·4		202·2		189·8		201·5		190·6	

* Not quite as good as A Grade. Valued at £165 per ton (approximately).

(iv) *Spinning.*

At the conclusion of the grading, 60 lb. of each lot was selected to contain a representative proportion of each of the grades of which the total was made up. These 60-lb. samples were processed for spinning into yarn suitable for shoe thread. As the slivers before spinning were approximately even, the fibre from each lot was spun simultaneously to approximately 13·5 lea. It was estimated that after boiling the lea value of the yarn would be 18 (approximate).

Fibre strength was determined on the yarn both before and after boiling. The yarn was conditioned at 70°F. and 70 per cent. relative

humidity, and 40 breaks were obtained on each sample. The rate of loading of the testing machine was 20 inches per minute. Breaking loads and unit strength values are shown in Table 3.

TABLE 3.—RESULTS OF SPINNING TESTS.

District	Benalla.				Gisborne.				Whorouly South.			
Variety	Liral Crown.		Concurrent.		Liral Crown.		Concurrent.		Liral Crown.		Concurrent.	
Experimental Lot Number	1.		2.		2.		4.		5.		6.	
	B.*	A.†	B.	A.	B.	A.	B.	A.	B.	A.	B.	A.
Lea value	14·4	21·1	13·7	17·3	13·9	17·9	14·4	19·4	13·6	17·6	13·6	18·3
Time conditioned hrs.	2	24	2	24	2	24	2	24	2	24	2	24
Average break .. lb.	6·2	4·2	4·8	5·1	5·4	5·0	4·4	4·1	6·0	4·9	4·8	4·0
Unit strength	89	89	66	89	74	90	63	79	82	87	65	74
Hackling yields ..	83·6		83·6		91·2		90·0		81·7		82·0	

* B. Before boiling. † A. After boiling.

3. Examination of Results.

(i) *Seed, Chaff, &c.*

In two of the comparisons (viz., Benalla and Gisborne) the seed yields from Concurrent were considerably higher than from Liral Crown, while in the third case the figures were almost identical for both varieties (see Table 1). Consequently the total deseeding losses for flax from the two former districts were higher for the Concurrent variety. Concurrent was evidently the greater seed-producing flax.

Yields of chaff were surprisingly constant for both varieties from each district. It would have been reasonable to expect, in the case of Benalla straw, when the yields of seed were 6·6 and 15·9 respectively for Liral Crown and Concurrent, that the chaff yields would have varied in the same manner. The corresponding chaff yields were 11·5 and 11·9. Similar results were obtained from Gisborne and Whorouly South straw, although in these instances the differences in the seed yields were not so high.

The percentages of weed, short straw, &c., taken out by the Soenens machine were quite small. These figures had no bearing on the comparisons, and only served to illustrate that any idea of saving this material, which was of a very bulky nature, for the sake of extracting the small amount of doubtful quality fibre which it contained, would almost certainly be very uneconomical.

(ii) *Fibre Yields.*

(*a*) *Line.*—Examination of the line fibre yields, calculated on the original weights, showed that in every instance Liral Crown gave a better performance than Concurrent. The percentage yield from Liral Crown was 2·3 per cent. better for Benalla flax and 0·9 and 1·9 per cent. higher for Gisborne and Whorouly South respectively, giving an average of 1·7 per cent. more fibre (on original weight) from Liral Crown. If £6 15s. per ton were paid for Concurrent, yielding the average figure of 12·1 per cent., then Liral Crown, producing an average of 13·8 per cent. fibre, would be worth £7 14s. per ton.

In the first two comparisons (Benalla and Gisborne) yields on deseeded weights were approximately the same for both varieties, and the higher yields from Liral Crown calculated on the original weights were due for the most part to less seed being obtained from the straw. In the case of Whorouly South flax this was not so. The 2·9 per cent. better yield on deseeded weight from the Liral Crown straw from this district must be taken as indicative of the better fibre-yielding properties of Liral Crown.

(*b*) *Tow.*—The higher tow values obtained from the Gisborne and Whorouly South flax were due to the unfortunate presence of considerable amounts of long weeds and oats which rendered the tow practically worthless. In consequence of this the line/tow ratios were low in value. Tow from the Benalla straw was of good quality and free from oats, &c. Liral Crown was again the better of the two, yielding only 4·0 per cent. tow as against 4·7 per cent. from the Concurrent.

(iii) *Ret Losses and Retting Times.*

The ret losses were variable and appeared to be independent of variety of straw. Concurrent from Whorouly South showed an abnormally high figure, and no reason can be given for it unless the presence of a relatively large amount of oats contributed.

Retting times varied from 90½ to 126 hours, and there was no relation between these figures and variety of flax.

(iv) *Grading.*

Details of grading set out in Table 2 clearly illustrated the superiority of Liral Crown flax from this point of view. No A grade was found in Liral Crown, and from two out of three of the districts (Benalla and Gisborne) no grade below C was present. Concurrent varieties invariably contained some A grade flax.

The average value for the three samples of Liral Crown worked out at £201 per ton of fibre, while for Concurrent flax the corresponding average value was £187 per ton. Calculating on a quality basis as well as from its fibre-yielding properties, if as before £6 15s. per ton of straw were the price paid for Concurrent flax, then Liral Crown would in all probability be worth £8 5s. 6d. per ton.

(v) *Spinning Tests.*

Hackling yields varied from 82 to 91 per cent., and were uniformly satisfactory for both varieties. No differences could be detected in the behaviour of the flaxes during processing. An abnormally high falling-off in lea value on boiling occurred with the yarn from Benalla Liral Crown, while in the other two cases the decrease in this value was slightly higher for the Concurrent varieties.

Unit strength values determined on the yarn before boiling showed that in every instance Liral Crown flax was stronger than Concurrent. After boiling, Liral Crown yarns from Gisborne and Whorouly South flaxes were still of better strength than those from Concurrent, while in the case of Benalla flax the unit strength values were the same for both varieties.

(vi) *Straw Yields.*

The general desire on the part of farmers to grow Concurrent flax in preference to Liral Crown appeared to be unjustified when it was found (Table 1) that in two out of three of these tests (Benalla and Gisborne) the yield of flax per acre was considerably better from Liral Crown, while in the Whorouly district the difference between the two yields was small. On the other hand, no account has been taken of the possibility that Concurrent may be a more robust type of flax, and consequently better able to withstand disease and drought. In each of the above districts the season during which the test flax was grown could be considered fairly favourable.

4. Conclusion.

The foregoing results have shown that Liral Crown was invariably a better proposition than Concurrent for fibre production, and it is probable that these results are independent of the growing district. It must therefore be recommended that Liral Crown variety of seed be reserved exclusively for resowing. At the same time, Concurrent has produced a fibre of considerable value, and it may be found advisable to resow a certain quantity of this variety annually and dispose of the remainder for other purposes. Farmers could be encouraged to grow Liral Crown in preference to Concurrent by offering a higher price for the former variety.

5. Acknowledgments.

Grateful acknowledgment is made to Mr. D. Birse for grading the fibre, and to James Miller and Co. Pty. Ltd. for carrying out the spinning tests.

The Genetics of *Ophiobolus graminis* Sacc.

1. Heritable Variations for Culture Colour and Pathogenicity.*

By N. H. White, M.Sc.†

Summary.

1. Heritable variations in pathogenicity on "Nabawa" wheat and culture colour on potato-dextrose agar occurred among the eight single ascospore isolates from a single ascus of *O. graminis*, and a Mendelian segregation of factors determining these variations occurred during ascosporogenesis.

2. Four phenotypes (two spores of each) were found as a result of segregation. These phenotypes were (i) dark and mildly pathogenic, (ii) dark and severely pathogenic, (iii) pale and mildly pathogenic, and (iv) pale and severely pathogenic.

3. The production of four pairs of spores in one ascus suggests that segregation for one pair of factors occurred in the first division, and for the other pair of factors in the second division of sporogenesis.

4. This can be explained on the assumption that crossing-over of one pair of factors occurred at the pachytene stage in the first nuclear division. This resulted in one pair of factors segregating reductionally at the first meiotic division and the other pair of factors segregating equationally at the second meiotic division of the primary ascus.

1. Introduction.

Among isolates of the fungus *O. graminis* Sacc., the writer found what appeared to be discontinuous variations in culture colour on potato-dextrose agar, and in pathogenicity on wheat. Variations in pathogenicity and culture characters amongst isolates of this fungus were reported by Davis (2), Russell (16), Krebs (10), Bussmann (1), Padwick (15), and Hynes (5).

To determine whether these variations in *O. graminis* are heritable, a genetic study was made of the fungus with reference to the characters for pathogenicity on a single variety of wheat and culture colour on potato-dextrose agar.

Segregation for these characters during ascosporogenesis is reported in this paper.

2. Material and Methods.

In a previous investigation the writer (17) obtained eight single-spore isolates from each of three asci. The isolates from two of these asci showed variation in colour when cultured on potato-dextrose agar. For the study of segregation, eight single-spore isolates from one ascus were used. Owing to the arrangement of the spores and to spore discharge in mass from the ascus, it was impossible to determine the order of their occurrence in the ascus.

Culture colour was determined after fourteen days' growth on potato-dextrose agar slopes incubated at 25°C.

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To determine if the isolates varied in pathogenicity, inoculation experiments on wheat were made in 6-in. pots under outdoor conditions. The pots were filled with a mixture of three parts loam and one part sand and were then steam-sterilized for six hours. The top 1½ inches of soil was removed and a 50-ml. beaker of soil inoculum* was distributed evenly over the exposed surface. About half an inch of the soil was then replaced and levelled. Ten grains of surface-sterilized "Nabawa" wheat were sown and covered with the remaining soil. Ten pots were inoculated with each isolate; these and the controls were block randomized. The experiments were begun in May of each year and the plants were harvested when mature. The soil was kept moist throughout the experiments.

In determining the pathogenicity of each isolate, the extent of damage from the seedling stage to harvesting was estimated, observations being made on each pot at intervals. Disease ratings were made at the seedling and jointing stages. The following formula for disease rating used by McKinney (14) and by Hynes (6) was adopted:—

$$\frac{\text{Sum of numerical ratings} \times 100.}{\text{Total number of germinated seed} \times \text{maximum disease rating.}}$$

3. Culture Colour Variations of Eight Isolates from a Single Ascus.

Colour variations in cultures of isolates of *O. graminis* have been noted by other workers. On carrot-dextrose agar, Padwick (15) noticed thallus colour differences between isolates, the differences being due to varying proportions of macrohyphae. Bussmann (1), comparing 21 isolates, observed that most of them were dark in colour but some developed only hyaline mycelium. Hynes (5), studying the characters of six isolates, noted differences in colour which ranged from dull white to greenish-grey.

On potato-dextrose agar slopes, four of the eight single-spore isolates from a single ascus were pale and four were dark. The type of growth of each of these isolates is shown in Plate 6. The colour of each group of four is due to the immersed mycelial mat and not to the aerial hyphae or underlying medium. In the dark cultures (numbers 1, 2, 3, and 4) the mycelium consists of both hyaline microhyphae and dark olivaceous macrohyphae, but in the pale ones (numbers 5, 6, 7, and 8) it consists entirely of hyaline microhyphae. Of the four dark cultures, isolates 1 and 2 are homotypes for the development of aerial hyphae, and isolates 3 and 4 are homotypes for flat colony surface. This may be seen in Plate 6. Of the four pale cultures, isolates 7 and 8 are homotypes for white aerial hyphae and isolates 5 and 6 are homotypes for flat colony surface. For over three years during which many sub-cultures were made, the culture characters remained constant for each of the eight isolates.

* Soil inoculum was prepared by placing 100 g. of air-dried soil (the same as used for the pots) in 10-oz. medicine bottles. These were placed on their sides, and 35 ml. of a solution containing 0·5 per cent. glucose and 0·05 per cent. "Marmite" were added; they were plugged and autoclaved. They were inoculated with small pieces of fungus culture and placed in a cupboard at room temperature. After six weeks' growth the mycelium had thoroughly permeated the soil, which was by then in a friable condition suitable for even distribution of inoculum. When required, the soil inoculum was removed from the bottles and mixed thoroughly.

4. Pathogenicity Variations of Eight Isolates from a Single Ascus.

Most of the variations in pathogenicity of isolates of *O. graminis* observed by past workers were determined by differential host reactions. However, Bussmann (1) and Russell (16) reported that isolates differed widely in pathogenicity on wheat. The effect of isolates on yield and height of plants was used by these workers in estimating pathogenicity.

The data obtained in the 1939 season from the pathogenicity test of the eight isolates are summarized in Table 1. It will be seen that each isolate is pathogenic to wheat. This is reflected in the total yield of grain, average grain weight, disease ratings, and the presence of empty ears on plants, as compared with the controls. Pathogenicity is also evident from the stunting and retardation of maturity in inoculated pots, illustrated in Plate 7. Some plants in the inoculated series eventually attained the height of the controls, but a number of them died prematurely at earing, presenting the characteristic features of take-all plants under field conditions. It will be noted that pathogenicity had no significant effect on the number of grains set per ear.

TABLE 1.—SUMMARY OF DATA OBTAINED IN 1939 FROM THE PATHOGENICITY TEST ON WHEAT OF EIGHT SINGLE-SPORE ISOLATES FROM A SINGLE ASCUS OF *O. graminis*.

Isolate.	Number germinated from 100 seed.	Disease rating at seedling stage.	Disease rating at jointing stage.	Number of plants failing to survive seedling stage.	Mean height at beginning of 5th month.	Total number of ears produced.	Number of empty ears.	Average number of grains per ear.	Average weight per grain.	Total yield of grain.
		%	%		cm.				mg.	g.
Control ..	91	0	0	0	43	103	0	9·0	38·3	34·94
1	83	47	53	29	20	39	25	7·0	24·1	1·83
2	83	46	67	32	18·7	32	16	10·0	12·0	2·11
3	90	70	91	67	5·2	11	10	10·0	16·0	0·18
4	97	78	83	75	5·0	4	2	7·0	15·6	0·20
5	88	71	81	61	8·4	17	12	10·0	23·2	0·18
6	80	61	84	53	9·2	14	12	6·0	14·8	0·19
7	83	25	38	18	22·0	51	25	8·0	23·0	6·81
8	86	30	43	23	21·3	24	24	10·0	18·4	1·90

Table 1 and Plate 7 clearly show that according to the degree of pathogenicity there are two groups of four isolates. One group is severely, and the other mildly, pathogenic; they may be distinguished primarily by their virulence on seedling wheat. The severely pathogenic group (isolates 3, 4, 5, 6) is characterised by the large number of plants killed as a result of seedling blight, and severe stunting of surviving plants. The yield from the surviving plants was negligible. The mildly pathogenic group (isolates 1, 2, 7, 8) is characterized by the relatively large number of plants surviving seedling blight and reaching maturity, and also by less stunting. Statistical analysis

showed that differences between these groups in disease rating, number of plants failing to survive the seedling stage, height of plants after five months' growth, and yield of grain, were all significant.

The pathogenicity test was repeated in 1940 under approximately the same environmental conditions. The pathogenicity of each isolate remained constant, and the same two groups were distinguished.

5. Variations of Eight Isolates from a Single Ascus for Culture Colour and Pathogenicity.

The characters of the eight isolates for both pathogenicity and culture colour may be seen by comparing Plates 6 and 7, and are shown in Table 2. From this, it is evident that there are four phenotypes, and two isolates belong to each phenotype. The ascus therefore contained four pairs of spores differing in character for pathogenicity on wheat and culture colour on potato-dextrose agar.

TABLE 2.—ISOLATES FROM A SINGLE ASCUS OF *O. graminis* GROUPED ACCORDING TO THEIR CHARACTERS FOR PATHOGENICITY AND CULTURE COLOUR.

Phenotypes.	1	2	3	4
Isolates	1, 2	3, 4	5, 6	7, 8
Pathogenicity	mild	severe	severe	mild
Culture colour	dark	dark	pale	pale

6. Inheritance of Culture Colour and Pathogenicity in *O. graminis*.

The thallus of *O. graminis* is haploid; therefore the effect of a single set of genes may be observed without the complications of dominance found in diploid structures where two sets of genes are present. The characteristics of each of the eight isolates, which were derived from a diploid primary ascus nucleus by reduction division, are due to a single set of genes. If the primary ascus was heterozygous for a pair of genes, segregation would occur in the reduction division, and four of the resulting ascospores would contain one of the genes and four would have the allelomorphs. If these allelomorphs produced different phenotypes there would be four of one and four of the other in the mature ascus. Since there are four isolates of each of two phenotypes for colour or for pathogenicity, segregation occurred during ascosporogenesis, and the primary ascus was heterozygous.

Although *O. graminis* is homothallic (White, 17), and its reproduction apogamous (Jones, 7) it may produce heterozygous asci, and such asci must have developed from ascogenous hyphae derived from different thalli. Combination of two strains could be effected through either (*a*) the phenomenon of heterocaryosis of Hansen and Smith (4), when a diploid or dicaryotic mycelium would be a pre-requisite for perithecial formation, or (*b*) the fusion of two

unrelated haploid vegetative cells in the developing perithecium, a possibility suggested by Jones (7). It appears, then, that crossing of strains resulting in new combinations may be effected even though the thallus of *O. graminis* is self-fertile. An attempt is being made to cross single-spore isolates of this fungus.

If the characters of the eight isolates for pathogenicity and culture colour are taken together, there is a pair of isolates belonging to each of four phenotypes, which could only be obtained if segregation occurred in two of the divisions of ascosporogenesis. This would occur in two successive reduction divisions if the fungus was brachymeiotic (Fraser and Welsford, 3), but Jones (7) reported that in *O. graminis* reduction of the diploid nucleus was effected in the first division of the primary ascus and resulted in four haploids at the end of the second division. Lindegren (11) found that segregation of factors for pale culture and sexuality in *Neurospora crassa* resulted in four kinds of spores of two each in one ascus, and that one pair of factors segregated in the first division and the other pair in the second division of the primary ascus. Keitt and Langford (8) reported similar changes in *Venturia inaequalis* when segregation for morphological characters produced four pairs of spores in the ascus. In both these fungi, reduction of the primary diploid ascus nucleus to four haploid nuclei is effected in the first two divisions. It is concluded therefore that in *O. graminis* segregation for one pair of factors occurred in the first division, and for the other pair in the second division. Lindegren (11) explained the two segreations in *N. crassa* on the basis of crossing-over of one pair of factors at the pachytene stage of the first nuclear division and reductional segregation of the spindle fibre attachment at the first meiotic division, providing the reduction of the diploid nucleus of the primary ascus to four haploids is effected in the first two divisions of the nucleus. Unlike *N. crassa*, spore sequence in the ascus of *O. graminis* could not be ascertained; consequently crossing-over in this fungus could not be determined. However, in the absence of any other explanation for the segregations in *O. graminis* it seems reasonable to apply Lindegren's explanation of crossing-over.

In *N. crassa*, the factor determining pale culture was located on the sex chromosome by Lindegren (12), and the crossing-over phenomenon with reference to the factors for pale culture and sexuality was described by Lindegren and Lindegren (13). In *O. graminis*, pathogenicity might be determined by a number of factors located on different chromosomes, but whether a strain is severely or mildly pathogenic on "Nabawa" wheat may depend on one factor. This also could apply to factors determining culture colour on potato-dextrose agar. The factor determining the degree of pathogenicity may or may not be on the chromosome determining culture colour. Fig. 1 illustrates the sequence of events during segregation if factors for pathogenicity and culture colour are on different chromosomes. *O. graminis* has four chromosomes in the haploid nucleus (Jones, 7), but only two are represented in Fig. 1.

The suggestion that characters for pathogenicity in *O. graminis* and other pathogenic ascomycetous fungi are Mendelian is supported by the fact that segregation for pathogenicity occurs during ascosporogenesis in *Venturia inaequalis* (Keitt and Palmiter, 9).

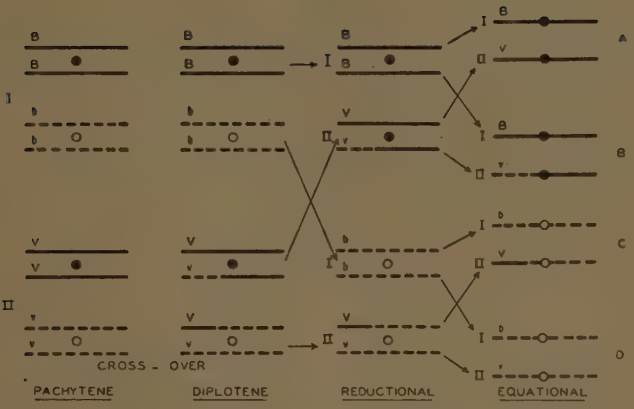

FIG. 1.—Segregation for culture colour B, b, and pathogenicity V, v, during ascosporogenesis in *O. graminis* when the factors are located on different chromosomes I and II.

7. Acknowledgment.

Thanks are due to Dr. J. R. A. McMillan for advice on the genetical aspects of this paper.

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The Effects of Sodium Chloride and of Two Manganese Salts on the Growth of Wheat and its Susceptibility to *Ophiobolus graminis* Sacc.

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Summary.

1. The growth of wheat in a field experiment was increased by potassium permanganate and decreased by sodium chloride. The difference between these treatments was significant, but the differences between either treatment and the control failed to reach the level of significance. Manganous sulphate had no significant effect. The growth was measured as total dry weight of aerial parts, harvested shortly before maturity.

2. In the same experiment, each of the above treatments was also applied to wheat inoculated with *Ophiobolus graminis*. This fungus significantly depressed the growth, but there was no evidence of interaction between the fungus and any of the salts.

3. In two experiments made in cans, in successive seasons, the pathogenicity of *O. graminis* to wheat was reduced by the addition of sodium chloride to the soil, at a concentration injurious to the wheat.

1. Introduction.

In parts of Australia, wheat is sometimes grown on soils of sufficiently high salinity to injure the crop. Teakle (5) states that in Western Australia sodium chloride generally constitutes about 70 per cent. of the total water-soluble salts in saline soils. It was thought by the writers that injurious concentrations of sodium chloride in the soil might increase the susceptibility of wheat to *Ophiobolus graminis* Sacc. This point was investigated by a field experiment in 1939, and by can experiments in 1939 and 1940. Machacek (4), working in Manitoba, showed that injurious concentrations of magnesium sulphate predisposed wheat to attack by *Fusarium culmorum* (W. G. Sm.) Sacc. and *Helminthosporium sativum* P. K. and B.

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Treatments with manganese salts were included in the field experiment as a separate line of study. Potassium permanganate is reported to facilitate the decomposition of soil humus and to increase the rate of carbon dioxide evolution from the soil (2, 3). It therefore seemed possible that, apart from its disinfectant properties, it might under some conditions affect the spread and pathogenicity of *O. graminis*. Treatments with manganous sulphate were also included, to give an indication whether any effects of the permanganate were attributable merely to the nutrient effect of its manganese content, or to the other factors mentioned above.

2. Field Experiment.

The field experiment was on a reddish-brown sandy loam of rather low fertility, at Black Mountain, A.C.T. The chemical treatments shown in Table 1 were applied to the soil immediately before the sowing of wheat. Half the rows of wheat were inoculated with *O. graminis*, the remainder receiving a similar amount of autoclaved inoculum. The eight treatments were replicated eight times in randomized blocks, the unit being a rod row sown with 100 selected grains of wheat (variety Union). The rows were a foot apart. An untreated guard row was interposed between each pair of treated rows.

Table 1.—Effects of Sodium Chloride, Manganese Salts, and Inoculation with *Ophiobolus graminis* on the Growth of Wheat in a Field Experiment.

Chemical Treatment Applied to the Soil in Each Rod Row.	Average Air-dry Weight (in grammes) of Nearly Mature Aerial Parts per Rod Row.		
	A. Treated with Sterilized Inoculum.	*B.* Inoculated with *Ophiobolus graminis*.	Mean of *A* and *B*.
None	479 ± 49	349 ± 49	414 ± 35
Sodium chloride, 450 g.	379 ± 49	252 ± 49	316 ± 35
Potassium permanganate, 60 g. ..	551 ± 49	404 ± 49	478 ± 35
Manganous Sulphate, 60 g. ..	469 ± 49	334 ± 49	401 ± 35
Mean for all chemical treatments and controls	470 ± 25	335 ± 25	402 ± 17

Differences equal to or greater than three times the standard error were considered significant.

The chemicals were applied as aqueous solutions, which were allowed to soak into furrows about 4 inches deep and 6 inches wide; these were then partially filled in with untreated soil, and the seed, superphosphate, and inoculum placed at a depth of 1½ inches, i.e., not in direct contact with the chemically-treated soil. Sodium chloride was applied at the rate of 450 g. in 1 gallon of water per rod row; each row occupied an area of 16·5 square feet. This was equivalent to about 0·13 per cent. of NaCl in the surface foot of soil, but the concentration was probably much higher in the root zone of the wheat

plants during the early stages of growth. According to Teakle (5), it was observed in Canada that poor growth of wheat occurred where the surface soil contained 0·12 per cent. of water-soluble salts; 0·25 per cent. might halve the yield. Greening (2) recommended the use of 1 ounce of potassium permanganate per square yard for stimulating the growth of lawns on light soils. The soil of the experimental area being light and very permeable, considerable leaching was expected, and a dressing slightly heavier than this amount was therefore applied, viz., 60 g. per rod row, dissolved in 1 gallon of water. The same weight of $MnSO_4$ was applied; this contained about 4·6 per cent. more Mn than the $KMnO_4$. Each control row received a gallon of water.

The inoculum was prepared by growing the fungus on a mixture of equal parts of potting soil and sand, moistened with an aqueous solution containing 2 per cent. of sucrose and 0·1 per cent. of peptone. This inoculum was used at the rate of 100 cc. per rod row. As the experimental area had been cropped with wheat during the previous three seasons, superphosphate was applied at the rate of 2 cwt. per acre. Records of emergence, seedling blight, and disease rating were kept, but they did not reveal any significant differences between treatments, other than those apparent at harvest. In order to avoid damage by birds, it was found necessary to harvest the plants before the grain had fully matured, and to dry them in the greenhouse. Ripening was somewhat uneven, and the premature harvesting resulted in slight pinching of the grain, the pinching being unevenly distributed amongst the treatments. The yields were therefore taken as air-dry weights of aerial parts; they are given in Table 1.

A significant reduction was caused by *O. graminis*; the yield from the rows treated with potassium permanganate was significantly higher than that from the rows treated with sodium chloride, though the differences between these treatments and the rows receiving no chemical treatment failed to reach the level of significance. Treatment with manganous sulphate had no significant effect. The interaction between *O. graminis* and the chemical treatments was not significant, showing that, under the conditions of the experiment, the effect of the organism on air-dry weight of aerial parts was not significantly influenced by any of the chemical treatments.

3. Can Experiments.

The effect of sodium chloride on the pathogenicity of *O. graminis* to wheat seedlings was tested by can experiments in 1939 and 1940. Nabawa wheat was sown during the autumn in 6-in. galvanized iron cans, each containing 2 kilogrammes of air-dry, dark grey, sandy loam. The technique of preparing and maintaining these cultures was similar to that used in experiments on flag smut (1). Fourteen hand-selected seeds were sown per can; the seedlings were thinned to give ten uniform plants per can. Sufficient cans were sown to provide at least 80 plants (with reserves to allow for accidental losses) for each of the four treatments shown in Table 2.

The fungus was grown on barley-oats mixture, 25 grains of inoculum being placed at seed level in each can of series B and D (Table 2). In 1940, about 5 grammes of soil inoculum was also added to each inoculated can. The controls were similarly treated with autoclaved

inoculum. The soil moisture was maintained at 50 per cent. of the water-holding capacity in 1939, and at 40 per cent. in 1940. In each year, 5 grammes of sodium chloride was added to each can in series C and D (Table 2), this being equivalent to 0·25 per cent. of the air-dry weight of the soil. One gramme per can was dissolved in the water applied at sowing, and 2 grammes were added with each of two waterings 15 and 30 days after the first.

The cans were kept outdoors, but protected from rain, for twelve weeks, after which the soil was washed out from the roots, and the total dry weight (including roots) of the plants in each can was determined. The results are given in Table 2. In both can experiments the total dry weight was significantly depressed by *O. graminis* and by NaCl separately, but the yield of dry matter from the inoculated cans treated with NaCl was significantly higher than that from the cans inoculated with *O. graminis* but not treated with NaCl. The culture of *O. graminis* used in 1940 originated from a single ascospore isolated by White (6), and was highly pathogenic. This may partly account for the much poorer growth of all inoculated plants in 1940 than in 1939. Its pathogenicity may have been accentuated by drier weather during the growing period than in 1939. Plate 8 shows washed-out plants from a typical can of each treatment in the 1940 experiment, eight weeks after sowing.

Table 2.—Effects of Sodium Chloride and of Inoculation with *Ophiobolus graminis* on the Total Dry Weight of Wheat Seedlings Grown in Cans.

Year.	Total Dry Matter (roots and tops) in g. per Can from each Treatment, after Twelve Weeks' Growth.				Significance of Differences.
	A. Control (no treatment).	*B.* Soil Inoculated with *O. graminis.*	*C.* NaCl, 5 g. per Can.	*D.* NaCl, 5 g. per Can, and Soil Inoculated with *O. graminis.*	
1939 ..	3·19	2·26	2·93	3·12	*B* significantly lower than *C*; both significantly below *A* and *D*. No significant difference between *A* and *D*.
1940 ..	3·22	0·50	1·86	0·70	All differences highly significant except that between *B* and *D*, which is significant at the 5 per cent. level

4. Conclusions.

In the field experiment, potassium permanganate gave a fairly substantial increase in average dry weight, although the difference between the yields from this treatment and the check was not significant. The lack of response to manganous sulphate suggests that there was no deficiency of Mn in the soil, and there is no evidence that the pathogenicity of *O. graminis* was reduced by $KMnO_4$. It therefore

appears likely that some other factor, e.g., the oxidation of soil humus, may have been concerned in any beneficial effect resulting from the application of $KMnO_4$.

In opposition to the results of the can experiments, the combination of *O. graminis* plus NaCl in the field experiment depressed the growth of wheat more than either treatment alone, though not more than the combined percentage depressions of the separate treatments, as compared with the controls. However, there was no significant interaction between the two treatments, and, owing to high variability, the results of this experiment were inconclusive with regard to the effect of NaCl on the pathogenicity of *O. graminis*.

On the other hand, the results of the two can experiments leave no room for doubt that, under the conditions of these experiments, the pathogenicity of *O. graminis* was reduced by the addition of NaCl. It is possible that a given injurious concentration of NaCl may reduce the growth of the fungal runner hyphae along the host roots as much as, if not more than, the growth of the host plant. These experiments certainly do not support the hypothesis that excess of NaCl in the soil may be a contributory factor to the infection of wheat by *O. graminis*. They suggest that the tolerance of this fungus to NaCl may be much less than that of *Fusarium culmorum* and *Helminthosporium sativum* to magnesium sulphate (4).

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Root Amputation Experiments with Wheat under Dry Conditions, in Relation to Attack by *Ophiobolus graminis* Sacc.

*By W. V. Ludbrook, B.Agr.Sc., Ph.D.**

Summary.

1. At four stages of growth, the root-systems of wheat plants in the field were injured by (*a*) severing the subcrown internodes, or (*b*) amputating the crown roots. The symptoms produced in the aerial parts by (*a*), and to a much smaller extent by (*b*), were indistinguishable from those exhibited by other plants in the same crop, of which the subcrown internodes or seminal roots were rotted by natural infection with *Ophiobolus graminis*.

2. The surface soil of the experimental area was very dry throughout most of the growth-period. Under these conditions, severing the subcrown internodes affected the plants more severely at all the stages of growth investigated than did amputation of the crown roots.

3. The results suggest that when the surface soil is dry, the main source of injury by *O. graminis* to wheat surviving the seedling stage may be lack of the moisture which would normally be drawn from the subsoil by the seminal root-system when not injured or destroyed by this fungus.

1. Introduction.

Root amputation experiments by Simmonds and Sallans (4, 5, 6) in Canada showed that the seminal roots of wheat were more important than the crown roots up to about midseason; under favourable conditions the crown roots became the principal absorbing system after this stage, although plants could produce seed when dependent almost entirely on the seminal roots. These authors discussed the bearing of their results on root diseases. Other workers (1, 2, 3) investigated the relative importance of the seminal and crown root-systems of wheat plants from a non-pathological viewpoint, with broadly similar results.

An area of natural pasture near Canberra was ploughed for the first time in 1938 and sown to Bencubbin wheat in 1939. Take-all (*Ophiobolus graminis* Sacc.) was abundant in this crop, and also in the second crop of the same variety grown in the same field in 1940. An intensive study of the epidemiology of the disease in this field was then begun by N. H. White (Assistant Pathologist, Division of Plant Industry). As a part of this project, the writer undertook the comparison of the effects of root amputation with those of natural infection of the roots with *O. graminis*. As the season progressed, the low and badly-distributed rainfall (Table 1) made it possible also to compare the effects of injuries to seminal and crown roots under conditions of intermittent drought. Accordingly, the small experiment initially planned was extended, as far as circumstances permitted, to take advantage of this opportunity. Although there were heavy rains before seeding, the top soil became very dry early in the growth period, and except after fair rains in September, remained so until harvest.

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TABLE 1.—MONTHLY RAINFALL AT CANBERRA FOR 1940, COMPARED WITH MEAN MONTHLY RAINFALL IN POINTS.*

——	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1940	185	10	6	696	115	52	29	91	244	25	70	177	1,700
Mean ..	191	167	210	186	180	204	176	217	167	218	192	204	2,312

* The crop was sown on April 29, and harvested on December 11.

2. Materials and Methods.

Simmonds and Sallans (5, 6) sowed individual seeds by hand, in widely-spaced rows. In some experiments they sowed the seed at a depth of 3 inches, to encourage the development of long subcrown internodes, which facilitated the work of root amputation. No such special provision was made in these experiments. Plants growing in the outside rows of ordinary drilled plots were used for the root amputations, and those in adjacent rows were used as controls. The shallow sowing and uneven spacing of the plants in the drilled rows considerably increased the difficulties of making root amputations, and the time required. Only a small number of plants could be treated in the time available.

Four series of amputations were done, at the stages of growth mentioned in Table 2. The technique of root amputation was similar to that described by Simmonds and Sallans (5, 6). In each series, the subcrown internodes of one lot of 10 to 20 plants were severed with a minimum of disturbance to the crown roots, and another lot was deprived of all crown roots without injuring the seminal roots. In series 3 and 4 (Table 2), these two lots were intermingled in the same row; in series 1 and 2, they were in separate rows, but each had its own controls in adjacent rows; the latter gave no evidence of any difference in the soil between the two locations. The soil on which the experiments were situated was a sandy loam varying from grey to brown, overlying a gravelly clay loam or clay subsoil.

TABLE 2.—STAGES OF GROWTH AT WHICH ROOT AMPUTATIONS WERE DONE.

Wheat sown on April 29, harvested December 11.

Series Number.	Date Treated.	Average Height of Plants in Cm.	Stage of Growth.
1	September 6	39	Pre-earing
2	October 5 ..	59	Ear-peeping to pre-flowering
3	October 30	80	Straw still green, grain ranging from milk to soft dough stages
4	November 11	74	Straw starting to go yellow, upper flags still green, grain at mid-dough stage

Time was not available for periodic removal of the new crown roots developing after amputation of the old ones. Except in series 1 and 2, there was little or no regeneration of crown roots, probably owing to the dryness of the surface soil. The observations in Table 3 were recorded before the regeneration of crown roots. The controls comprised (*a*) untreated plants, (*b*) plants treated by removing and replacing the soil about the crowns, as was necessary in doing the root amputations. This treatment had no significant effect (Tables 4 and 5).

3. Effect of Root Amputations on Aerial Parts.

The observations summarized in Table 3 were made in the field, beginning within four days of treatment and continuing at frequent intervals until harvest. Plants showing no visible effect were rated 0, slight injury 1, and severe injury or premature death 2. Cutting the subcrown internode before earing rapidly produced symptoms in the aerial parts indistinguishable from those following early and severe attack of the seminal root-system by *O. graminis*, viz., wilting, yellowing, and tip-withering of the foliage and marked stunting or cessation of growth.

Table 3.—Numbers of Wheat Plants Assigned Various Ratings for Severity of Injury to Aerial Parts following Amputations of the Crown Roots or Subcrown Internodes.

Rating for Severity of Injury.	Date of Treatment.							
	September 6.		October 5.		October 30.		November 17.	
	Crown Roots Cut.	S.C.I.* Cut.	Crown Roots Cut.	S.C.I. Cut.	Crown Roots Cut.	S.C.I. Cut.	Crown Roots Cut.	S.C.I. Cut.
0	4	..	7	2	6	..	9	1
1	4	3	3	5	5	4	5	15
2	2	8	..	6	..	8	..	..
Significance of difference between treatments† ..	P = ·00517		P = ·00237		P = ·00009		P = ·00109	

* S.C.I. = subcrown internode.

† The significance figure for September 6, for example, is the chance that 21 plants, of which 4 are rated 0, 7 are rated 1, and 10 are rated 2, could be partitioned into two groups of 10 and 11 plants with ratings equally or more unfavourable to subcrown internode cutting than were obtained experimentally. It was assumed that severity of injury was proportional to the rating.

The aerial parts of older plants dried out prematurely, changing rapidly from green through greyish-green to almost white, instead of slowly through yellowish-green to yellow. The dry straw was much lighter and more brittle than that of normal plants, and the ears were narrow, bleached and erect, closely resembling the conditions known as "whiteheads" or "haying off" which developed naturally in plants affected by *O. graminis* in other parts of the same field. White (7) showed that the severity of symptoms in the latter plants was closely correlated with the extent to which their seminal root-systems were invaded by *O. graminis*.

Some of the plants of which the crown roots were amputated reacted in a similar way, but to a much smaller extent than those of which the subcrown internodes were cut. The difference in response was highly significant in each series (Table 3). No plants showing any signs of attack by *O. graminis* were included in the amputation experiments. Any experimental plants of which the roots were found after harvest to show signs of fungal attack were discarded.

4. Effect of Root Amputations on Grain-size.

Each experimental plant was assigned a rating for grain-size after harvest, by separately threshing the grain from each ear, placing it in a petri dish, and matching it visually with one of a set of standard samples of grain, ranging from 1 (extremely pinched: grain-weight below ·005 g.) to 14 (very plump: grain weight ·0651 to ·07 g.), the intervals of grain weight being ·005 g. The mean grain-size rating for each plant was calculated by averaging the ratings for the separate ears, and for each treatment by averaging the means for each plant. The results are shown in Table 4, and the significance of differences in Table 5.

TABLE 4.—EFFECT OF ROOT AMPUTATIONS ON GRAIN-SIZE OF WHEAT.

Treatment.	Date of Treatment.							
	September 6.		October 5.		October 30.		November 17.	
	No. of Plants.	Mean Rating for Grain Size.	No. of Plants.	Mean Rating for Grain Size.	No. of Plants.	Mean Rating for Grain Size.	No. of Plants.	Mean Rating for Grain Size.
Control untreated	..	..	37	9·078	39	8·119	40	10·087
Control—soil about crowns disturbed	10	9·00	39	8·648	26	8·463	..	..
Crown roots cut ..	8	6·906	10	8·708	11	5·666	14	8·559
Subcrown internodes cut ..	11	5·962	12	5·719	12	2·877	16	6·234

TABLE 5.—SIGNIFICANCE OF DIFFERENCES BETWEEN TREATMENTS IN TABLE 4.

Comparison.	Date of Treatment.			
	September 6.	October 5.	October 30.	November 17.
Control (untreated) v. Control (disturbed)	..	N.S.	N.S.	..
Control v. Crown roots cut ..	N.S.	N.S.	$P < ·001$	$P < ·001$
Control v. S.C.I. cut ..	$·01 > P > ·001$	$P < ·001$	$P < ·001$	$P < ·001$
Crown roots cut v. S.C.I. cut	N.S.	$·05 > P > ·01$	$P < ·001$	$P < ·001$

N.S. = Not significant at the 5 per cent. level.

Each series of plants with severed subcrown internodes produced grain which was more shrivelled than that from the comparable series of plants with severed crown roots, the differences in mean rating for grain-size being significant for all but the earliest growth-stage (Table 5). Disturbance of the soil about the crowns of a portion of the control plants had no significant effect on grain-size, indicating that the effects attributed to root amputation were not partly caused by the unavoidable disturbance of the proximal parts of the remaining roots.

In series 3 and 4 (October 30 and November 17), covariance analyses of grain-size corrected for variation in tiller number gave results of the same order of significance as the analyses of variance. The regression coefficients were negative, i.e., the plants with most tillers suffered most severely from root amputation, but only the coefficient for series 4 was significant at the 5 per cent. level.

5. Effect of Root Amputations on Yield.

Differences between treatments in mean weight of grain or in total dry matter were much less significant in each series than were differences in mean grain-size. In no series was there a significant difference in yield of grain or total dry matter between plants with crown roots amputated and those with subcrown internodes cut. However, the failure to obtain significant yield differences does not invalidate the results given in Tables 3 and 4, and may be due to chance variations in yield predetermined by factors operating before the root-amputations were done. If larger numbers of plants could have been treated, it is possible that significant differences in yield between treatments might have occurred.

6. Discussion and Conclusions.

The symptoms produced in the aerial parts of wheat plants by (*a*) artificially severing the subcrown internode, (*b*) destruction of the seminal root system by *O. graminis*, appeared identical in the field. This suggests that in a dry season the main source of injury by *O. graminis* to wheat surviving the seedling stage may be lack of the moisture which would normally be drawn from the subsoil by the seminal roots. Under these conditions, there seems no necessity to postulate any toxic action of the fungus on the aerial parts, although this possibility is not excluded. There was a profuse development of crown roots on most of the plants from which they were not removed, but there was little or no evidence of fungal attack on either the crown roots or the stem bases when examined after harvest. Under wet conditions these may, of course, be severely attacked.

The results are thought to demonstrate the primary importance of the seminal roots with regard to moisture supply at all stages of growth investigated, under the conditions of these experiments. Although the season was unusually dry for the locality, moisture conditions were probably more favourable than those under which wheat is often grown throughout large parts of the Australian wheat belt, as indicated by the average yield of 18 bushels per acre from the rest of the experimental crop, which was on rather poor soil and received no special treatment. It may well be that the importance of the seminal root system under Australian conditions is greater than is generally realized.

Observations made during a survey of the central and south-western slopes of New South Wales in early November, 1940, supported the view that probably many of the crops in these areas depended largely on moisture drawn from the subsoil by their seminal root-systems throughout the growth-period.

These experiments were admittedly inadequate to assess the effects of root amputation on yield resulting from a reduction in the supply of nutrients, which might reasonably be supposed to come from the top soil, via the crown roots, to a much greater extent than from the seminal roots.

Simmonds and Sallans (6) found that ripening was delayed by severing the subcrown internodes, but in the writer's experiments, plants so treated ripened prematurely. This difference is attributed to the fact that, in the latter experiments, water absorption by the crown roots was minimized by drought.

7. Acknowledgments.

The writer gratefully acknowledges his indebtedness to Mr. G. A. McIntyre, Assistant Biometrician, C.S.I.R., for suggesting the method of rating for grain-size described in Section 4, and for the statistical examination of the numerical data.

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A Study of the Toxicity of Australian Vertical Retort Creosote Oils to *Lentinus lepideus* Fr., *Polystictus versicolor* (L.) Fr., and Madison 517.

*By David E. Bland, M.Sc., A.A.C.I.**

Summary.

1. Australian vertical retort creosotes were found to be of substantially the same toxicity as horizontal retort oils. Results differed somewhat according to the test fungus used, but no large difference was detected in the toxicity of oils of approximately the same distillation range.

2. Vertical retort oils of lower creosote boiling range are more toxic than those of higher creosote boiling range.

3. The most toxic fraction of vertical coal tar oil is that distilling between 225°C. and 275°C.

4. The largest contribution to the toxicity of the vertical retort oils is made by the tar acids.

5. The most toxic fractions of the tar acids are those boiling above 250°C.

6. Consideration of the toxicity of a creosote and the toxicity of its constituents shows that the constituents do not act independently of one another.

7. It is pointed out that the most toxic oil may not necessarily prove to be the most satisfactory wood preservative.

1. Introduction.

Toxicity to wood-destroying organisms is one of the essential properties of a satisfactory wood preservative. Up to the present, no studies of the toxicity of Australian creosotes have been reported. Overseas literature contains many accounts of excellent studies of the toxicity of creosotes to wood-destroying fungi; practically all of these refer to horizontal retort and coke oven creosotes. The only creosotes available in large quantities in this country are vertical retort creosotes.

Australian vertical retort creosote oils do not conform to either the British or American specifications for creosote oils for wood preservation purposes because of their low specific gravity. The current British specification (3) does, however, include the clause: "When creosote from low temperature tar is ordered, the specific gravity S. 38°C./20°C. shall not be lower than 0·935 nor higher than 1·065." This would allow Australian vertical retort creosote (S. 38°C./20°C. 0·95–0·99) to pass as creosote from low temperature tar. Although these vertical retort oils do resemble low temperature products in many respects, the temperature in the retorts during their production is quite high. Their resemblance to low temperature oils is due to the nature of the coal, the absence of a hot space in the retorts, and the fact that the gas is speedily withdrawn from the retorts, so that cracking of the primary products of pyrolysis is minimized.

Numerous methods have been proposed for assessing the toxicity of creosotes to wood-destroying fungi. All of these fall into one of the following classes: agar tests, wood flour tests, wood block tests. The main features of these tests are outlined below.

In the agar test, a series of dishes of malt agar medium, containing different concentrations of the preservative, is prepared. The dishes

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are inoculated with cultures of the test fungi and then incubated under standard conditions for two weeks. At the end of this time, the lowest concentration of preservative causing complete inhibition of growth is noted. The principal criticism of this test is that the substrate is not the natural one. Furthermore, agar medium when kept in a petri dish may lose water by evaporation and thus cause a change in the concentration of the preservative. When used with a volatile preservative, such as creosote, vapour from one dish may repress fungal growth in neighbouring dishes. Bateman and Henningson (2) have overcome these last two objections by the use of sealed culture vessels large enough to contain sufficient air for the normal growth of the fungus during the test period. This modification has been adopted in the standard method proposed by Schmitz and others (7).

The wood block method was standardized at a conference in Berlin in 1930 (4). This test is carried out with small wood blocks of known oven-dry weight. These are impregnated with a solution or emulsion of the preservative, and the solvent or dispersion medium allowed to evaporate. The blocks are placed in jars containing a vigorously growing culture of the test fungus and incubated for three or four months. At the end of the incubation period the blocks are oven-dried and re-weighed to determine the loss of weight. The lowest concentration of preservative preventing loss of weight is recorded as the toxic point. The wood block provides a natural substrate, but its use is open to other objections. It is difficult to ensure a uniform concentration of preservative throughout the block, any concentration of preservative at the surface of the block leading to serious error. The results obtained vary with the species of wood used. Furthermore, no two pieces of wood—even from the same tree—are identical.

Reeve (5) used wood flour as a medium by adding the preservative in benzene, allowing the benzene to evaporate, and pressing the wood flour into a disc. The disc thus prepared is inoculated with the test fungus and incubated. Once again, the lowest concentration of preservative causing complete inhibition of fungal growth is noted. Wood flour cannot be regarded as the natural substrate; in it, the structure of the wood has been destroyed, and the properties of wood are intimately connected with its structure.

Laboratory determinations of toxicity can give only relative results. The concentration of creosote required in practice to maintain the concentration of preservative above the toxic point during many years of service is far above the minimum concentration determined by any toxicity test. Since the agar method gives relative results quite satisfactorily and in a much shorter time than other methods, it was adopted in the present investigation.

2. Oils Tested.

(*a*) Australian vertical retort creosotes A, B, C, D, E, F, a specimen of an American creosote and a specimen of a European creosote. The distillations and analyses of these oils are given in Table 1.

(*b*) Tar acids; tar bases; aromatic hydrocarbons; paraffins and naphthenes—derived from creosote B.

(*c*) (i) Fractions from creosotes A, B, and C, as set out in Table 6

(ii) Fractions of tar acids from creosote B as set out in Table 5.

3. Experimental Procedure.

(a) Selection of Creosote Samples.

The standard specification for creosote oil (1) permits wide variation in the distillation range with consequent wide variation in the physical, and possibly in the toxic, properties of the oil. Three samples of oil A, B, and C, from one still of tar, were selected to cover the extreme variation in boiling range likely to be encountered in practice. Another set of three samples D, E, and F were taken from the one still of a tar from another source. The sample of American creosote was obtained from the Forests Products Laboratory, Madison, Wisconsin, U.S.A., and that of European creosote from the International Advisory Office on Wood Preservation, The Hague, Holland. It is realized, of course, that these creosotes also are subject to large variations in distillation range and nature.

(b) Distillation and Analysis of Creosotes.

The specific gravity of each oil was determined by means of a Westphal balance. The standard distillation as described in the Australian Standard Specification (1) was carried out. The results are shown in Table 1.

TABLE 1.—ANALYSES AND DISTILLATION RANGES OF CREOSOTES.

		Australian Vertical Retort Creosotes.						American Creosote.	European Creosote.
		A.	B.	C.	D.	E.	F.		
S.G. 38°/20° ..	..	0·948	0·963	0·982	0·963	0·981	0·991	1·089	1·039
Distillation (Australian standard)	0–205° C. ..	5·7	0·8	1·4	1·7	0·7	0·1	0	0·1
	0–230° C. ..	39·3	2·5	2·5	27·4	1·1	0·1	1·9	5·0
	0–315° C. ..	91·5	55·1	20·2	87·8	61·9	43·6	47·4	63·6
	Residue ..	Soft paste	Soft paste	Soft paste	Oily	Soft paste	Soft paste	Green paste	Oily
Distillation (volume)	0–200° C. ..	4·7	0·7	2·9	1·7	0·8	0	0·6	0·4
	0–210° C. ..	14·3	1·5	3·2	4·4	0·8	0	0·7	0·4
	0–220° C. ..	24·0	2·0	3·8	13·4	0·8	0	1·2	0·9
	0–230° C. ..	37·5	3·0	4·5	28·2	0·9	0	2·7	5·5
	0–240° C. ..	50·2	4·5	5·3	38·6	2·4	0	5·7	12·7
	0–250° C. ..	58·8	7·7	6·4	50·4	6·1	0	9·8	22·6
	0–260° C. ..	66·7	12·7	8·1	59·0	10·6	3·2	13·9	32·0
	0–270° C. ..	73·0	16·7	10·1	66·2	19·1	4·0	20·6	40·2
	0–280° C. ..	78·4	22·5	11·2	72·0	27·5	9·5	25·0	49·3
	0–290° C. ..	83·2	31·2	12·3	77·3	37·2	15·8	32·1	55·2
	0–300° C. ..	86·3	40·2	15·6	81·6	46·6	24·4	38·6	61·1
	0–310° C. ..	89·5	48·7	17·7	85·3	55·1	35·8	42·7	66·9
	0–320° C. ..	92·2	58·2	22·1	88·7	63·6	46·1	49·8	72·7
	0–330° C. ..	94·0	66·2	27·9	91·1	71·2	55·8	55·1	78·0
	0–340° C. ..	..	74·2	35·5	..	78·0	65·0	61·6	82·5
	0–350° C. ..	..	81·0	43·9	..	83·8	72·5	68·4	87·0
	0–360° C. ..	..	87·5	54·1	..	89·0	79·1	75·1	91·0
	Residue ..	Oily	Soft paste	Soft paste	Soft paste	Soft paste	Soft paste	Soft and sticky	Black and oily
Analysis (percentages)	Tar acids ..	25·9	17·0	16·9	24·4	20·2	17·4	6·0	6·3
	Tar bases ..	4·0	3·8	4·2	3·9	4·8	4·4	6·1	6·2
	Unsaturated hydrocarbons	5·0	8·0	10·0	4·0	8·0	11·0	11·0	9·0
	Aromatic hydrocarbons	33·5	31·2	29.3	38·9	33·5	33·6	76·9	78·5
	Paraffins and naphthenes	31·6	40·0	39·6	28·8	33·5	33·6	nil	nil

The volume distillation was carried out using the standard creosote testing apparatus with the receiving flask replaced by a 100-ml. graduated cylinder. The creosote sample was measured out in the

cylinder and transferred, as completely as possible by draining, into the clean, dry distillation flask. The apparatus was then assembled, the cylinder being placed in its position as receiver without being wiped out. The distillation was then carried out at the rate of two drops per second, the volume of distillate being noted every 10°C. Since the amount of oil distilling below 200°C. was in all cases small, the first reading was taken at that temperature. These distillations were carried out in duplicate. The average values are shown in Table 1.

For the chemical analysis, 100 ml. of the oil was pipetted into a separating funnel and extracted with 50 ml. of hot 10 per cent. sodium hydroxide, and then with successive portions of 20 ml. until the extracting liquid remained colourless. The phenolate solution was run from the separating funnel into a distilling flask, and the bulked washings were boiled until no oil distilled over with the water. The water layer of the distillate was separated off and discarded; the oil layer was returned to the neutral oil. This oil layer was usually about 1 ml. in volume.

The phenolates in the flask, after cooling, were acidified with hydrochloric acid to liberate the phenols and the entire liquid transferred to a tar acid funnel, the last traces being washed in with saturated sodium chloride solution. After settling for at least two hours, the volume of tar acids was read.

Next, the tar bases were extracted from the neutral oil by washing with 50 ml. of sulphuric acid (25 per cent. H_2SO_4 by weight), and then with successive portions of 20 ml. until the acid remained colourless. The second 20-ml. wash was usually colourless. To the combined acid washings 30 per cent. sodium hydroxide was added until the solution became alkaline. This caused the tar bases to separate as a flocculent semi-solid mass which formed a layer, too ill-defined to render possible their determination by direct measurement, on the surface of the aqueous layer. In order to separate the tar bases, the alkaline solution, containing the tar bases in suspension, was agitated with 50 ml. of benzene. After settling, the aqueous layer was drawn off and discarded and the benzene solution of the bases was run into a tared 150-ml. distillation flask. The flask was then fitted with a thermometer and condenser and the benzene distilled off. The distillation was continued until the tar bases began to boil and the distillation ring touched the thermometer and caused the mercury thread to rise suddenly; the flame was then quickly removed. This procedure was adopted in order to prevent any benzene refluxing from the upper parts of the flask. After cooling, the flask plus tar bases was weighed and the weight of tar bases obtained by difference. This gave the number of grammes of tar bases from 100 ml. of oil. Since the rest of the analysis was carried out by volume, the number of ml. of tar bases was calculated assuming a specific gravity of 1·06. This value was obtained by testing bulked tar bases recovered from a number of determinations. The degree of precision attainable in these analyses was not considered sufficient to warrant a semi-micro specific gravity determination in every case.

To determine the unsaturated hydrocarbons, the tar acid, tar base, free oil was run into a 250-ml. stoppered, graduated cylinder, its volume noted, and an equal volume of sulphuric acid (80 per cent. H_2SO_4 by

weight) added. The oil and the acid were then agitated for 60 seconds and allowed to stand for one hour, when the contraction in volume of the oil was noted.

The oil thus freed from tar acids, tar bases, and unsaturated hydrocarbons was used to determine the paraffins. Four ml. of this oil was taken in a 10-ml. stoppered, graduated cylinder and 6 ml. of dimethyl sulphate added. The mixture was agitated for one minute and then allowed to stand for half an hour, when the volume of the supernatant layer of paraffin was read.

The term paraffin is here used to include both paraffins and naphthenes. These two groups of compounds are so similar in physical and chemical properties that their separation cannot be effected by chemical means. Determination of the proportion of paraffins and of naphthenes in a mixture of the two by means of the aniline point applies only to a mixture of fairly narrow boiling range and cannot very well be applied to the whole range from a creosote.

The aromatic hydrocarbons were determined by difference.

(c) Distillation of Oils into Fractions.

Creosote oil is always tested by simple distillation and not by any process of rectification. In order to demonstrate as clearly as possible the relationship between the distillation range of creosote as customarily determined, and its toxicity, three oils, A, B, and C, were distilled into fractions in an apparatus similar to the standard creosote testing apparatus. The oils were separated into fractions of 25°C. range commencing at 200°C. When the quantity of any of the lower fractions was small, it was included in the next higher fraction. Thus, in the case of creosote B the fractions 200°–225°C. and 225°–250°C. were so small that they were included in one fraction up to 250°C.

Tar acids, obtained from creosote B as described in (*d*) (i) below, were distilled into 25°C. fractions in the same way.

(d) Resolution of Creosote into Components.

(i) *Tar Acids.*—One litre of creosote B was taken and washed free of tar acids with 10 per cent. sodium hydroxide. The phenolate solution was distilled and the oil which distilled over was separated from the water and returned to the neutral oil. The tar acids were liberated with hydrochloric acid and separated off in the usual way.

(ii) *Tar Bases.*—The neutral oil was washed free from tar bases with 25 per cent. sulphuric acid and the bases liberated from the acid solution with 30 per cent. sodium hydroxide.

(iii) *Unsaturated Hydrocarbons.*—In order to remove unsaturated hydrocarbons, the oil thus freed from tar acids and tar bases was shaken with successive quantities of sulphuric acid (80 per cent. H_2SO_4 by weight) until the acid remained colourless.

(iv) *Paraffins and Naphthenes.*—For the separation of aromatic hydrocarbons from paraffins and naphthenes, the following procedure was adopted:—200 ml. of the oil freed from tar acids, tar bases, and unsaturated hydrocarbons, as outlined above, were shaken with 200 ml. of dimethyl sulphate in a separating funnel. After settling, the dimethyl sulphate layer was drawn off, a further 100 ml. of dimethyl sulphate

added to the oil in the funnel and the mixture again agitated. The second quantity of dimethyl sulphate was drawn off and added to the first. The remaining paraffin and naphthene fraction was washed, first with 10 per cent. sodium hydroxide until the washings were free from sulphate, and then several times with water.

(v) *Aromatic Hydrocarbons.*—The dimethyl sulphate solution of the aromatic hydrocarbons was boiled under a reflux condenser with 500 ml. of 10 per cent. sodium hydroxide for 30 minutes; the aqueous layer was then acid. After removing the aqueous layer, a further 500 ml. of sodium hydroxide was added and the boiling continued for another 30 minutes; at the end of this period the aqueous layer was alkaline. The total amount of alkali thus used was far less than equivalent to the quantity of dimethyl sulphate. Dimethyl sulphate is readily hydrolysed by water. The alkali was used to ensure the complete removal of dimethyl sulphate from the oil. The liberated aromatic hydrocarbons were washed with water until free from alkali.

(e) *Toximetric Method.*

For culture vessels 1½-lb. wide-mouth jars were used; 36 ml. of the culture medium consisting of 2 per cent. malt extract and 2 per cent. agar in water was pipetted into each jar. The jars containing the medium were sterilized under 10 lb. per square inch pressure of live steam for 30 minutes.

During the sterilization of the jars, 44·34 g. of the oil to be tested was weighed into the cup of a high-speed stirrer. Sufficient 10 per cent. gum acacia solution was then added to the oil to make the total volume 200 ml. and the mixture stirred until completely emulsified. Preliminary tests made by growing the test fungi on media containing varying amounts of gum acacia showed that the growth rates of the fungi were not affected by the gum acacia.

Tar acids were emulsified with a 5 per cent. solution of animal glue, since gum acacia was found not to be a satisfactory emulsifier for these compounds.

The 22·17 per cent. stock emulsion so obtained was then diluted with distilled water to give a series of more dilute emulsions shown in Table 2. One ml. of the stock emulsion was added to each of six jars containing the agar hot from sterilization, thus giving a medium containing 0·6 per cent. (grammes per 100 ml.) of creosote. Similarly, six jars of each concentration set out in Table 2 were prepared by the addition of 1 ml. of the appropriate diluted emulsion. Six jars without creosote were kept for use as controls. After the medium solidified, two jars of each concentration were inoculated with each of the test fungi, viz., *Lentinus lepideus, Polystictus versicolor,* Madison 517. The inocula were taken from fourteen-days-old cultures of the test fungi growing in petri dishes on a 1-mm. thick layer of medium.

The test cultures were incubated for fourteen days at 26°C. The radial growth was measured every other day. At the end of the incubation period the lowest concentration of creosote causing complete inhibition of growth was noted. Those inocula showing no growth were replanted on malt agar in petri dishes and incubated for a further fourteen days; those which did not grow were assumed to be dead. The lowest concentration of creosote causing death of the inoculum was

recorded as the killing concentration. When the fungus grew on all concentrations included in the test, further cultures were prepared on media containing 1·0, 2·0, and 3·0 per cent. of creosote. Higher concentrations were not tried even if growth occurred on the medium containing 3·0 per cent. creosote. When no growth occurred on any of the concentrations given in Table 2, additional cultures containing 0·005 per cent. and 0·01 per cent. of the oil were prepared.

TABLE 2.—QUANTITIES TAKEN IN DILUTING THE ORIGINAL EMULSION TO THE REQUIRED CONCENTRATIONS.

Quantity of 22·17 per cent. emulsion.	Quantity of Water.	Concentration of Creosote (g. per 100 ml.) given by 1 ml. of diluted emulsion plus 36 ml. of agar medium.
ml.	ml.	
2	58	0·02
2	28	0·04
2	18	0·06
2	13	0·08
5	25	0·10
5	15	0·15
10	20	0·20
10	10	0·30
10	5	0·40
20	4	0·50
..	0	0·60

4. Results.

The results of the tests on the various creosotes are shown in Table 3. From these data it is at once apparent that the more volatile oils were the more toxic to all three of the test fungi. Australian creosotes of similar distillation range but of different origin showed no significant difference in toxicity. This was to be expected since their chemical compositions, given in Table 1, were very similar.

TABLE 3.—THE TOXICITY OF CREOSOTES.

Creosote.	Per cent. Distilling below 315°C.	*Lentinus lepideus.*		*Polystictus versicolor.*		Madison 517.	
		Inhibiting Concentration.	Killing Concentration.	Inhibiting Concentration.	Killing Concentration.	Inhibiting Concentration.	Killing Concentration.
	%	%	%	%	%	%	%
A	91·5	0·08	0·3	0·06	0·08	0·06	0·06
B	55·1	0·2	1·0	0·3	0·6	0·2	0·2
C.	20·2	0·2	1·0	0·5	1·0	0·3	0·3
D	87·8	0·06	0·3	0·06	0·08	0·08	0·10
E	61·9	0·10	0·5	0·3	0·5	0·10	0·10
F	43·6	0·15	2·0	0·3	1·0	0·2	0·2
European ..	63·6	0·3	Over 3·0	0·15	0·5	0·2	0·3
American ..	47·4	0·15	Over 3·0	0·08	1·0	0·15	1·0

Compared with an Australian oil (E) of similar distillation range, the European creosote proved to be less toxic to *Lentinus lepideus,* more toxic to *Polystictus versicolor,* and less toxic to Madison 517, than E.

The American creosote had the same inhibiting concentration as F to *L. lepideus,* but was more toxic to *P. versicolor* and Madison 517; it was, however, slightly more volatile than F.

The toxicities of the constituents of creosote B are shown in Table 4. The tar acids were most toxic. *L. lepideus* proved least resistant to them, being killed by 0·02 per cent. The tar bases were only slightly less toxic than the tar acids. *L. lepideus* was killed by 0·04 per cent. of tar bases; the other two fungi resisted higher concentrations than this. The aromatic hydrocarbon fraction was practically non-toxic to *L. lepideus,* which grew on the medium containing 3·0 per cent. The growth of *P. versicolor* was inhibited by the same concentration of aromatic hydrocarbon as of original oil (0·3 per cent.); but whereas in the case of the original oil the fungus was killed by twice that concentration, ten times the concentration of aromatic hydrocarbon failed to kill it. Madison 517 was inhibited by 2·0 per cent. but was not killed by 3·0 per cent. The paraffins and naphthenes were practically non-toxic; all three of the test fungi grew—at a reduced rate—on media containing 3·0 per cent.

Table 4.—The Toxicity of the Constituents of an Australian Vertical Retort Creosote.

	Lentinus lepideus.		*Polystictus versicolor.*		Madison 517.	
	Inhibiting Concentration.	Killing Concentration.	Inhibiting Concentration.	Killing Concentration.	Inhibiting Concentration.	Killing Concentration.
	%	%	%	%	%	%
Tar acids	·02	·02	·04	·06	·02	·04
Tar bases	·04	·04	·04	·15	·04	·08
Aromatic hydrocarbons ..	Over 3·0	..	0·3	Over 3·0	2·0	Over 3·0
Paraffins and naphthenes ..	Over 3·0	..	Over 3·0	..	Over 3·0	..

The results of the tests on the tar acid fractions are shown in Table 5. *L. lepideus* showed a steadily decreasing resistance from the lower to the higher fractions, the most toxic fractions being the very viscous, almost solid, fraction from 325° to 350°C. The fraction most toxic to *P. versicolor* was that from 250° to 275°C. Madison 517 was most affected by the fractions between 250° to 325°C.

Table 5.—Toxicity of Tar Acid Fractions.

Fraction.	*Lentinus lepideus.*		*Polystictus versicolor.*		Madison 517.	
	Inhibiting Concentration.	Killing Concentration.	Inhibiting Concentration.	Killing Concentration.	Inhibiting Concentration.	Killing Concentration.
	%	%	%	%	%	%
—225°	0·04	0·08	0·04	0·06	0·04	0·06
225°—250°	0·04	0·06	0·04	0·06	0·04	0·04
250°—275°	0·02	0·06	0·02	0·04	0·02	0·02
275°—300°	0·02	0·06	0·04	0·06	0·02	0·02
300°—325°	0·02	0·06	0·06	0·06	0·02	0·02
325°—350°	0·01	0·04	0·08	0·08	0·02	0·04

From the specific gravity data given in Table 6, it is apparent that the same fraction from two different creosotes is not necessarily an identical oil. For example, the fraction from 300° to 325° from creosote B has a specific gravity of 0·965, whereas the fraction of the same range from creosote C has a specific gravity of 0·974. It is therefore not unexpected to find a difference of toxicity between two such fractions.

The inhibiting and killing concentrations determined for each fraction against each fungus are set out in Table 6. Considering all three fungi, the most toxic fractions were those from 225° to 250° and 250° to 275°C.; the higher fractions were less toxic. *Lentinus lepideus* showed rather different results from the other two fungi in that the inhibiting concentration of the higher fractions was quite low; these were apparently as effective as the lower fractions. This, however, does not apply if we judge toxicity by the killing concentration which showed a regular increase (i.e., decrease of toxicity) from the lower to the higher fractions. The other two fungi indicated a fairly regular decrease of toxicity from the lower to the higher fractions with regard to both the inhibiting and killing concentration.

TABLE 6.—TOXICITY OF CREOSOTE FRACTIONS.

Creosote.	Fraction °C.	S.G. 38°/20°.	*Lentinus lepideus.*		*Polystictus versicolor.*		Madison 517.	
			Inhibiting Concentration.	Killing Concentration.	Inhibiting Concentration.	Killing Concentration.	Inhibiting Concentration.	Killing Concentration.
			%	%	%	%	%	%
A ..	–225° ..	0·946	0·06	0·30	0·06	0·10	0·06	0·06
	225°–250° ..	0·953	0·06	0·30	0·06	0·06	0·04	0·04
	250°–275° ..	0·947	0·06	0·20	0·04	0·10	0·04	0·04
	Residue over 275° ..	..	0·15	2·0	0·40	1·0	0·10	0·10
B ..	–275° ..	0·956	0·15	0·30	0·08	0·15	0·08	0·08
	275°–300° ..	0·969	0·10	0·60	0·10	0·30	0·06	0·10
	300°–325° ..	0·965	0·06	1·0	0·15	0·50	0·08	0·08
	325°–350° ..	0·966	0·10	3·0	0·50	3·0	0·10	0·10
	Residue over 350° ..	1·015	0·30	3·0	Over 3·0	..	2·0	2·0
C ..	–300° ..	0·913	0·10	0·50	0·10	0·20	0·15	0·15
	300°–325° ..	0·974	0·06	0·60	0·08	0·20	0·15	0·20
	325°–350° ..	0·982	0·08	Over 3·0	0·50	2·0	0·30	0·30
	Residue over 350° ..	1·006	0·30	Over 3·0	Over 3·0	..	2·0	3·0

5. Discussion.

Lentinus lepideus was used as a test fungus because it is known to be particularly resistant to creosote oil, and is often found growing close to the creosoted portion of timber. *Polystictus versicolor* was included because it is the commonest sap rot fungus occurring in Australia. Both *L. lepideus* and *P. versicolor* have been extensively used as test organisms in toxicity work. Madison 517 was included because—under the name of *Fomes annosus*—it has been proposed (7) as the standard test fungus and extensively used in agar tests. Its use

enables comparison with the results of a considerable amount of other toxicity work. Richards (6) has pointed out that its doubtful identity in no way affects the value of these results.

The importance of using a number of test organisms is shown by the distinctive behaviour of each of the test fungi. Only in one case (creosote A) was the concentration of vertical retort creosote required to inhibit the growth of *L. lepideus* higher than that required to inhibit *P. versicolor* or Madison 517. On the other hand, the concentration of creosote required to kill *L. lepideus* was consistently higher than that required to kill the other two. The gap between the inhibiting and killing concentrations was much larger for *L. lepideus* than for *P. versicolor*. In the case of Madison 517, the gap was very small or absent altogether. This gap may be only a function of the growth rate of the fungus. The incubation of a slow-growing fungus like *L. lepideus* for the same time as the rapid-growing Madison 517 may not give a true comparison of their respective resistances to the preservative. In one experiment, cultures of *L. lepideus* which had not grown in 14 days were not replanted, but were incubated for a further 14 days; at the end of this time some had commenced to grow. Thus, the "inhibiting concentration" determined for 28 days' incubation period was higher than that determined for 14 days' incubation. Presumably, if the incubation period were extended far enough, the gap between the inhibiting and killing concentrations would disappear.

Any attempt to arrange the creosotes in order of toxicity gives quite different results according to the test fungus and whether the inhibiting or killing concentration be taken as a measure of toxicity. The two most volatile oils (A and D) are, however, the most toxic judged by the inhibiting or killing concentration for any fungus.

The high toxicity of the tar acids and relatively low toxicity of the other constituents of the creosote indicates that the tar acids make the chief contribution to the toxicity of Australian vertical retort oils. The tar bases also are very toxic, but the percentage of tar bases is small compared with the percentage of tar acids.

That the tar acids do not act independently of the other constituents of the oil is clear from the following analysis. Knowing the composition of a creosote and its inhibiting concentration, we may readily calculate the concentration of each constituent in the inhibiting medium. This has been done for creosote B and the figures are shown in Table 7. This calculation gives no information regarding the

TABLE 7.—PERCENTAGES OF CREOSOTE CONSTITUENTS IN THE MEDIUM AT THE INHIBITING CONCENTRATION.

—	*Lentinus lepideus.*	*Polystictus versicolor.*	Madison 517.
	%	%	%
Tar acids	0·034	0·051	0·034
Tar bases	0·008	0·011	0·008
Unsaturated hydrocarbons	0·016	0·024	0·016
Aromatic hydrocarbons ..	0·062	0·094	0·062
Paraffins and naphthenes	0·080	0·120	0·080
Creosote	0·200	0·300	0·200

distribution of any constituent between the oil and water phases, but merely gives the total concentration of the constituent in the inhibiting medium. Comparing the percentage of tar acids present at the inhibiting concentration of the creosote with the toxicity of the tar acids given in Table 4 shows that, in the case of the whole creosote, the concentration of tar acids was, for all three fungi, somewhere near 50 per cent. greater than the inhibiting concentration of tar acids alone. Even at the next lower concentration of 0·15 per cent., on which growth occurred, the corresponding concentration of tar acid is 0·025 per cent., which is higher than the inhibiting concentration of the tar acids alone. The concentration of tar bases was quite low, but high enough to exert a by no means negligible retarding action on the growth of the fungi, since the tar bases are very toxic.

Where the inhibiting concentration of creosote B (for *L. lepideus* and Madison 517) was 0·2 per cent., this means that the concentration of aromatic hydrocarbons was 0·062 per cent. In the toxicity test on the aromatic hydrocarbons, *L. lepideus* grew on a medium containing 0·060 per cent. at the rate of 4·9 mm. per day, while the control grew 6·7 mm. per day. In other words, 0·06 per cent. of aromatic hydrocarbons retarded the growth rate of *L. lepideus* by 27 per cent. Similarly 0·06 per cent. of aromatic hydrocarbons retarded the growth rate of Madison 517 by 73 per cent. For *P. versicolor* the inhibiting concentration of creosote B was 0·3 per cent., which corresponds to 0·094 per cent. of aromatic hydrocarbons, 0·10 per cent. of which, in the toxicity test, retarded the growth rate of *P. versicolor* by 83 per cent. Since the toxicity of the paraffin portion is low and its concentration in the inhibiting medium also low, its toxic effect may be neglected.

Considering only the tar acids and aromatic hydrocarbons, it is apparent that much more than sufficient toxic material was present at the inhibiting concentration of the whole creosote than would be necessary to prevent growth if the constituents acted independently of one another.

In conclusion, it must be stressed that toxicity to wood-destroying organisms is only one of the requirements of a wood preservative. A highly toxic oil may not necessarily be satisfactory as a preservative. In addition to being toxic originally, the oil must remain toxic after years of service. A high initial toxicity is desirable, but an oil which retains its toxicity well is better than one with a high initial toxicity, but which rapidly loses toxicity in service. Work is at present in hand to determine the permanence of various creosote oils.

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The Damping Capacity of Timber.

*By W. L. Greenhill, M.E.**

Summary.

The physical significance of "damping capacity" is discussed together with its use in evaluating materials for aircraft construction. A description is given of investigations made of the damping capacity of various timbers by measuring the logarithmic decrement of free flexural vibrations and also free torsional vibrations. Results show that timber has a greater damping capacity than any of the metals commonly used for aircraft construction.

The effects of moisture content on damping capacity and the damping capacity of "improved" wood are also considered.

Introduction.

The physical significance of the "damping capacity" or "internal friction" of structural materials is the subject to-day of considerable investigation and discussion. Briefly, the term "damping capacity" is used to describe the ability of a solid to convert mechanical energy of vibration into internal energy. This causes vibrations to die out. If a truly elastic material is subjected to a cycle of stress, the stress-strain curve will be a straight line. If, however, the material undergoes reversible plastic deformation during the cycle, the stress-strain curve will be a hysteresis loop. The area enclosed by this loop represents the amount of energy expended during each complete stress cycle. If vibrations are started in an elastic material there is no tendency for them to die out unless this effect is produced by external conditions. All solids, however, have a certain degree of internal friction resulting in an unavoidable degradation of energy which manifests itself in various ways. It causes the gradual damping of a vibrating solid even when the solid is so supported as to transfer none of its energy to the surroundings. It has been shown that specimens subjected to cycles of stress below the fatigue limit can dissipate an unlimited quantity of energy as heat without any damage.

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When a solid is subjected to a periodic force, the damping capacity prevents the amplitude of vibration from becoming infinite when the frequency of the applied force approaches a natural frequency of the solid. Damping capacity is of considerable importance in certain branches of engineering and, consistent with other properties, it is generally agreed that materials of high damping capacity are superior to those of low damping capacity. Take, for example, the wings of aeroplanes. Under certain circumstances these are subject to resonant vibrations, the amplitude of which depends essentially on the damping properties of the materials of construction. The same thing applies with special force to the blades of aeroplane propellers which are liable to vibrate violently at certain critical speeds of rotation. The amplitudes of vibration are great or small according to the material of which the blades are made. It is stated by experts that the endurance of the blades depends far more on the damping capacity of the material than on its fatigue strength.

Various measures have been postulated for expressing damping capacity. Thus, if $\triangle E$ is the energy dissipated per cycle and E the maximum energy of the cycle, the ratio $\frac{\triangle E}{E}$, called the specific energy loss, gives a measure of the damping capacity of the solid.

Observation of the rate of decay of free vibrations provides a simple means for determining the logarithmic decrement, and it is this measure of damping capacity that has been adopted in the tests to be described in the present article.

Of the various methods evolved for measuring damping capacity, that of free torsional vibrations has perhaps received most attention. Contractor and Thompson (1) have recently described very well designed apparatus employing this method.

A comprehensive bibliography of published information relating to damping capacity and its measurement is given by Kimball (2). Practically all investigations of which records are available have been concerned with metals and only occasional references are made to wood. The results given in the present article are of tests conducted on a number of Australian timbers selected because of their possible value in aircraft construction. Two series of tests have been carried out, one employing flexural and the other torsional vibrations.

Experimental.

Apparatus.

In the design of apparatus for measuring damping capacity by means of either flexural or torsional vibrations, one of the main considerations is to see that damping due to incidental losses is small. Losses may be due to air friction, friction of recording mechanism, or absorption of part of the energy of swing by tremors set up in the supporting foundations. For these reasons the inertia of the vibrating system should be large, the rate of vibration slow, and the equipment should be supported in such a way as to transmit as little energy as possible to the foundations. With torsional vibrations the apparatus is usually suspended by a thin wire.

For the first series of tests in which flexural vibrations were considered, the equipment was in the nature of a temporary expedient and it is probable that incidental losses were higher than would generally be desirable. However, special effort was made to see that the conditions of testing were the same for all specimens, so that as a means of comparison between different species and different moisture contents the results should be of value.

The specimens were in the form of laths, carefully machined to finished dimensions of $1\frac{1}{2}$ inches x $\frac{1}{4}$ inch x 36 inches long. In testing, each specimen was securely held by a machine vice mounted on the table of a milling machine. The jaws of the vice were 6 inches wide and gripped an area of the specimen 6 inches by $1\frac{1}{2}$ inches. The mounted specimen extended along the table of the milling machine, the free end approaching the spindle. An 8-in. diameter drum was mounted on the spindle and a stylus on the free end of the wood specimen in such a way that as the drum revolved a record was made on its surface of any lateral movement of the free end of the specimen.

After the specimen had been mounted and the drum started, the free end of the specimen was displaced 1 inch and released. The resultant curve obtained was used for computing the logarithmic decrement of the vibrations.

The second series of tests was made with torsional vibrations, using the standard type of instrument manufactured by the Cambridge Instrument Co. Ltd. The design of test specimen used in this instrument is shown in Fig. 1, the instrument itself in Fig. 2. The oscillations are recorded by a stylus attached to the inertia bar and moving over a celluloid disc rotated by a clock. The record on the disc is examined and measured by means of a special microscope.

Material Tested.

Flexural Vibrations.—A quartersawn specimen was obtained from each of six different trees of the following species:—

King William pine (*Athrotaxis selaginoides* D. Don).
Celery top pine (*Phyllocladus rhomboidalis* L. C. Rich).
Blackwood (*Acacia melanoxylon* R. Br.).
Bunya pine (*Araucaria bidwilli* Hook).
Queensland silver ash (*Flindersia bourjotiana* F. v. M.).
Northern silver ash (*Flindersia pubescens* F. M. Bail.).
Hoop pine (*Araucaria cunninghamii* Ait.).
Sitka spruce (Canadian) (*Picea sitchensis* Trautvetter and Meyer).
Bollywood (*Litsea reticulata* Benth.).
White birch (*Schizomeria ovata* D. Don).
Queensland maple (*Flindersia mazlini* F. M. Bail.).
Silver quandong (*Elaeocarpus grandis* F. v. M.).
Sassafras (*Doryphora sassafras* Endl.).
Scented satinwood (*Ceratopetalum apetalum* D. Don).
Mountain ash (*Eucalyptus regnans* F. v. M.).
Alpine ash (*Eucalyptus gigantea* Hook.).

In addition, backsawn specimens were prepared from the first eight species.

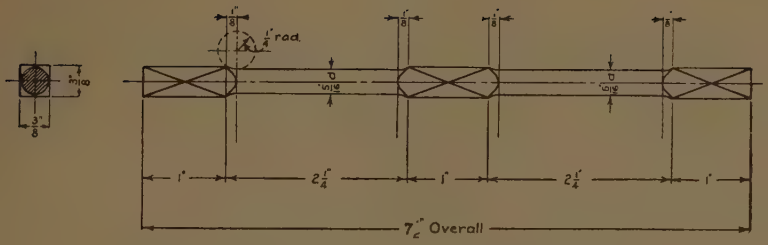

Fig. 1.—Torsional Damping Machine, English Test Piece.

Before testing, all the material was conditioned for several weeks to a constant moisture content of approximately 15 per cent.

A number of the specimens were conditioned subsequently to moisture contents of first 8 per cent. and then 19 per cent. and tested at each of these conditions.

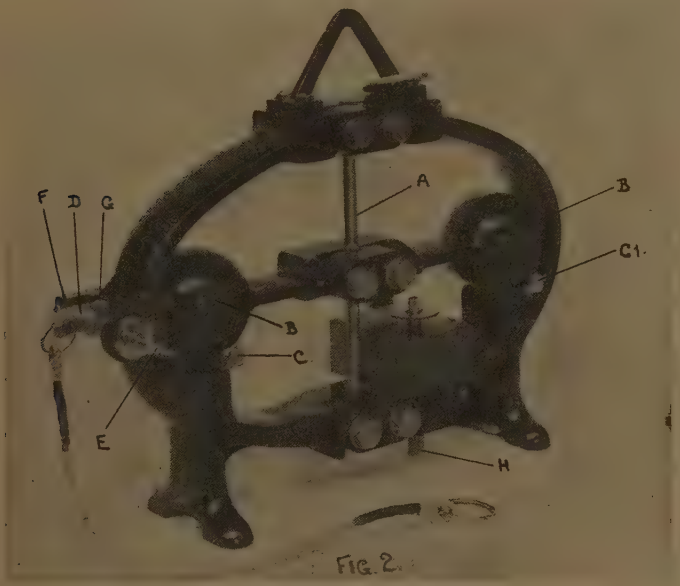

Fig. 2.—Torsional damping recorder.

Torsional Vibrations.—One specimen was prepared from each of two different trees of the above sixteen species. In addition, a number of specimens of improved wood was included. These were of various densities and resin contents.

All specimens were conditioned in a 15 per cent. moisture content room before testing.

Results.

Flexural Vibrations.

Table 1 gives the specific gravity and logarithmic decrement for the sixteen species tested. The values are the averages of six quartersawn specimens and are in descending order of logarithmic decrement.

TABLE 1.—COMPARISON OF SPECIES.

(*Average of 6 quartersawn specimens.*)

Species.	Sp. Gr.	Log Decrement.	$E/10^6$.
King William pine	·391	·0497	0·78
Celery top pine	·588	·0420	1·42
Blackwood	·643	·0363	2·02
Bunya pine	·497	·0360	1·80
Northern silver ash	·681	·0352	1·84
Spruce	·450	·0350	1·73
Bollywood	·445	·0349	1·24
Queensland silver ash	·654	·0348	1·47
White birch	·657	·0348	1·79
Queensland maple	·574	·0339	1·61
Silver quandong	·470	·0333	1·41
Hoop pine	·578	·0332	1·97
Sassafras	·668	·0313	2·20
Scented satinwood	·628	·0306	2·08
Mountain ash	·707	·0272	2·76
Alpine ash	·661	·0260	2·36

In addition, the elastic modulus (E) as determined from these tests is tabulated. Details of the method of determining E are given by Worsnop and Flint (3).

Table 2 compares the results obtained with quartersawn and backsawn specimens from six trees of each of eight species.

TABLE 2.—COMPARISON OF QUARTERSAWN AND BACKSAWN SAMPLES.

(*Average of 6 specimens.*)

Species.	Sp. Gr.		Log Decrement.		$E/10^6$.	
	Q.	B.	Q.	B.	Q.	B.
King William pine ..	·391	·387	·0497	·0558	0·78	0·70
Celery top pine ..	·588	·582	·0420	·0426	1·42	1·36
Blackwood	·643	·659	·0363	·0358	2·02	2·07
Bunya pine	·497	·467	·0360	·0337	1·80	1·78
Northern silver ash ..	·681	·671	·0352	·0360	1·84	1·74
Spruce	·450	·448	·0350	·0369	1·73	1·62
Queensland silver ash ..	·654	·631	·0348	·0332	1·97	1·86
Hoop pine	·578	·560	·0332	·0330	1·97	1·92
Average	·560	·551	·0378	·0384	1·69	1·63

Table 3 shows the effect of moisture content on the various properties.

TABLE 3.—EFFECT OF MOISTURE CONTENT.

(*Average of* 1 *backsawn and* 1 *quartersawn specimen of each species except for Mountain Ash and Alpine Ash, for which* 1 *quartersawn specimen only was used.*)

Species.	Sp. Gr.			Log Decrement.			$E/10^6$.		
	8 per cent.	15 per cent.	19 per cent.	8 per cent.	15 per cent.	19 per cent.	8 per cent.	15 per cent.	19 per cent.
King William pine	·364	·380	·382	·0477	·0530	·0557	0·76	0·74	0·71
Celery top pine	·516	·542	·546	·0348	·0414	·0410	1·55	1·48	1·47
Blackwood ..	·495	·510	·514	·0337	·0356	·0384	1·65	1·59	1·68
Bunya pine ..	·404	·427	·434	·0321	·0340	·0361	1·66	1·62	1·56
Northern silver ash	·689	·711	·712	·0316	·0382	·0388	1·73	1·65	1·57
Spruce ..	·466	·480	·488	·0331	·0385	·0389	1·76	1·71	1·65
Queensland silver ash	·596	·607	·626	·0303	·0333	·0339	2·22	2·17	2·13
Hoop pine ..	·450	·469	·477	·0301	·0324	·0346	1·84	1·83	1·75
Mountain ash ..	·673	·681	·685	·0286	·0274	·0294	2·38	2·41	2·34
Alpine ash ..	·674	·688	·695	·0302	·0315	·0326	2·58	2·71	2·60
Average ..	·533	·550	·556	·0332	·0365	·0379	1·81	1·79	1·75

Table 4 compares the values of E as obtained by vibration tests with the values obtained by static bending.

TABLE 4.—COMPARISON OF ELASTIC MODULI OBTAINED BY VIBRATION METHOD AND STATIC BENDING.

(*Average of* 1 *backsawn and* 1 *quartersawn specimen of each species except Mountain Ash and Alpine Ash, for which* 1 *quartersawn specimen only was used.*)

Species.	Elastic Modulus ($E/10^6$).		
	(1) Vibration Method.	(2) Static Bending.	Ratio $\frac{(1)}{(2)}$
King William pine	0·74	0·75	0·99
Celery top pine	1·48	1·47	1·01
Blackwood	1·59	1·58	1·01
Bunya pine	1·62	1·46	1·11
Northern silver ash ..	1·65	1·65	1·00
Spruce	1·71	1·57	1·09
Queensland silver ash ..	2·17	2·10	1·03
Hoop pine	1·83	1·84	0·99
Mountain ash	2·41	2·00	1·21
Alpine ash	2·71	2·50	1·08
Average	1·79	1·69	1·05

Torsional Vibration.

Table 5 gives for each species tested the average value of the specific gravity and logarithmic decrement. In addition, the logarithmic decrement obtained from flexural vibrations on specimens cut from

the same boards as the torsion specimens have been listed to enable a comparison to be made of the two methods.

TABLE 5.—COMPARISON OF SPECIES.

(*Average of 2 specimens.*)

Species.	Sp. Gr.	Logarithmic Decrement.		Mod. Rigid. x 10^{-5}.	
		Torsion.	Flexure.	Vibrations.	Static.
Sassafras	·66	·0592	·0312	0·93	..
King William pine	·41	·0581	·0542	1·35	1·19
Blackwood	·69	·0575	·0346	1·60	..
White birch	·66	·0575	·0351	1·08	..
Bunya pine	·44	·0562	·0364	1·00	0·98
Scented satinwood	·66	·0558	·0286	1·19	..
Celery top pine	·55	·0540	·0376	1·20	..
Spruce	·46	·0521	·0365	1·38	..
Bollywood	·44	·0517	·0345	0·92	..
Alpine ash	·68	·0517	·0257	1·19	1·16
Queensland silver ash ..	·66	·0516	·0334	1·14	..
Northern silver ash	·69	·0514	·0337	1·24	..
Silver quandong	·46	·0483	·0339	0·91	..
Mountain ash	·69	·0482	·0265	1·12	1·10
Hoop pine	·54	·0473	·0329	1·44	1·04
Queensland maple	·57	·0458	·0339	1·31	..

The modulus of rigidity of these test pieces is proportional to (frequency of vibration)^2 so that by comparison with a metal specimen of known modulus it has been possible to calculate the modulus of the timber specimens. These results are also given in Table 5 together with the modulus of rigidity of a few of the species as obtained by static torsion tests on a much wider range of material.

Table 6 gives the results obtained by torsional damping tests of a number of specimens of improved wood.

TABLE 6.—TORSIONAL DAMPING TESTS ON IMPROVED WOOD (from scented satinwood veneer).

(*Average of two specimens.*)

Description of Specimen.	Percentage Resin.	Specific Gravity.	Log. Decrement.	Mod. Rig. x 10^{-5}.
Scented satinwood (solid)	0	·66	·0558	1·19
1/16-in. veneer, glued with casein ..	0	·73	·0676	1·07
" " " " ..	0	·69	·0674	1·08
1/16-in. veneer, resin impregnated ..	20	1·03	·0458	1·78
" " " "	31	1·04	·0426	1·82
" " " " ..	40	1·04	·0418	2·10
1/24-in. veneer, resin impregnated ..	40	1·29	·0414	2·96

Discussion.

A comparison of the damping capacity of timber as found in either of the present series of tests with published results for metals shows that timber has a much greater damping capacity than any of the

metals commonly used for aircraft construction. The logarithmic decrement as determined from torsional vibrations is in all cases higher than that from flexural vibrations, but, in general, the order of the species is much the same for the two series of tests. Exceptions are sassafras and scented satinwood, which are much higher in the list in the torsion tests. On account of the heterogeneous nature of wood, it is not unexpected that the damping capacity varies with different types of vibration.

There does not appear to be any significant difference between the behaviour of backsawn and quartersawn specimens except perhaps in the case of King William pine for which the damping was greatest for the backsawn specimens, i.e., with the plane of vibration perpendicular to the growth rings.

An examination of Table 3 shows that the effect of increasing the moisture content of a specimen is to increase its damping capacity, the relation being practically linear within the range tested. The effect of moisture content on the elastic modulus as determined by vibrations is quite small, a fact which confirms the relation found by static bending tests.

Table 4 compares the values of the elastic modulus found by the method of vibrations with those found by static bending. The agreement is good in most cases, although on the average the vibration method gives a figure some 5 per cent. higher than that obtained by static bending.

Judging from the few comparisons available, it appears that the modulus of rigidity as determined by torsional vibrations is also slightly greater than that determined from static torsion tests.

The results on improved wood indicate clearly that with an increase either in resin or density the damping capacity is reduced and the rigidity modulus increased.

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Studies on Chemical Weed-killers with Special Reference to Skeleton Weed.

4. Further Spray Trials and Toxicity Investigations with a Note on Translocation.

By C. G. Greenham, M.Sc., and T. Wilkinson, B.Sc.†*

Summary.

Following the application of an acid arsenical spray to skeleton weed (*Chondrilla juncea* L.), the length of the subterranean axis killed was significantly greater at ten days than at four days after spraying.

During a wet season, the effectiveness of the spray was increased both by increasing the concentration of arsenic pentoxide and by decreasing the concentration of sulphuric acid.

Further toxicity trials were made. Arsenic pentoxide, arsenic trioxide, additional organic arsenicals, sodium chlorate, "Sinox", kerosene, a kerosene solution of lead tetraethyl, sodium sulphide, and tar oils were among the poisons used.

Evidence was obtained that arsenic pentoxide, if applied to skeleton weed without any additional penetrating agent, can be translocated downwards as a result of metabolic activities.

1. Introduction.

The investigations reported herein were a continuation of earlier work (3). They were made to obtain information concerning the time factor in relation to the length of axis killed, the optimal concentration of penetrating agent and translocated poison, and to test the toxicity and ease of translocation of likely poisons. Among the substances tested were some organic arsenicals (tested for the first time as herbicides) and some non-arsenicals reported to have given promising results with other plants (5, 7).

The technique previously described (3) was used on established skeleton weed plants at the Wagga Experiment Farm. The sprays were applied at the rate of 150 gallons per acre.

On account of the limited spraying season, the experiments were made in two successive years.

2. Experiments and Results.

(*a*) *The Time Factor in Relation to the Length of Axis Killed.*

The purpose of this experiment was to ascertain if the length of the killed subterranean axis depends upon the time interval between spraying and examination. The spray solution consisted of 9 per cent. (by weight) of sulphuric acid, 0·85 per cent. arsenic pentoxide, and 0·025 per cent. ‡sodium lauryl sulphate.

On the 7th October, 1938, between 5.15 and 5.20 p.m., thirty selected skeleton weed plants were sprayed. They were in two rows

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‡ Concentration of sodium lauryl sulphate refers to the concentration of the commercial product (du Pont IN–181), which contained 27·3 per cent. carbon, 4·7 per cent. hydrogen, and 59·0 per cent. ash.

of fifteen plants each. The results were statistically analysed and are summarized in Table 1. According to this table, the values observed 10 days after spraying are significantly greater than those observed four days after. Although the treatments were not randomized, it is considered that no serious errors were thereby introduced, because the plants were so close together. The short period of time during which the spray applications were made should eliminate the time-of-day effect (3).

Table 1.—Length of Axis Killed in Relation to Time Interval After Spraying.

(*All lengths given in inches.*)

—	Row A. (Four days after spraying.)	Row B. (Ten days after spraying.)	Standard Error.	Difference for Significance.
Arith. Mean ..	3·58	12·03	± 1·40	4·2

($t = 4·27$, $n = 28$. This value highly significant.)

(b) Optimal Concentration of Penetrating Agent and Translocated Poison.

The investigations of Crafts (1) suggest that there may be an optimal concentration of both penetrating agent (sulphuric acid) and translocated poison (arsenic trioxide), but do not, in the absence of statistical treatment, give any conclusive evidence. The following experiments were accordingly done, arsenic pentoxide being used instead of the trioxide, on account of its probably greater remote toxicity (3).

In 1938 an experiment to determine the optimal concentration of sulphuric acid was made, the range of concentration of acid being from 1·0 N to 3·5 N. From the analysis of variance of the results (logarithmic data) the differences were not significant. However, a comparison of the treatment means of the actual observations suggested a definite decrease in effectiveness with increasing concentration, the effect of which was masked by the high experimental error.

The above suggestion was confirmed during 1939, when some information regarding the optimal concentration of arsenic was also obtained. There were 20 different treatments (*A* to *T*), each being replicated four times in duplicate ("block-pairs") in order to overcome the influence of time of day. The application of the various treatments was randomized as regards time, with the exception that within any one replication the duplicate treatments were done together. Spraying operations lasted from 2.40 to 4.30 p.m., on the 26th October. The day was bright and sunny in the morning, reasonably warm with a slight breeze, but the sky was overcast from 3 p.m. onwards; the soil was moist, more than an inch of rain having fallen a few days previously. The sprayed plants were excavated on the 7th and 8th of November. Rain exceeding 1½ inches fell during the interval between spraying and excavating.

Table 2 summarizes the statistical analysis of the results. From it is seen the differences between the acid concentrations and also between the arsenic concentrations were significant. There was not a significant interaction between the acid and the arsenic concentrations, indicating

that the reactions to the different concentrations of acid were the same for all strengths of arsenic, and vice versa. There were some significant differences between pairs of blocks that were treated at different times.

TABLE 2.—DATA FROM OPTIMAL CONCENTRATION OF ACID AND ARSENIC PENTOXIDE EXPERIMENT.

(a) Analysis of Variance.

Source.	D. of F.	Sum of Squares.	Mean Square.	F.	Significance.
Between treatments—					
Acids	4	44·75	11·19	3·42	Nears 1 per cent.
As. concentrations ..	3	115·61	38·54	11·79	1 per cent.
Interaction ..	12	30·61	2·55	0·78	Not significant
Between blocks—					
Between pairs ..	3	61·47	20·49	6·27	1 per cent.
Within pairs ..	4	12·78	3·20	0·98	Not significant
Error ..	132	431·83	3·27	..	
Total ..	158	697·05	..	..	

(b) Treatment Means.

P.	T.	L.	K.	F.	G.	Q.	R.	M.	S.	O.
5·23	4·81	4·68	4·36	4·11	3·64	3·63	3·61	3·55	3·26	3·14

H.	N.	B.	J.	E.	A.	I.	C.	D.	Difference for Significance.
2·95	2·89	2·31	2·01	1·99	1·98	1·96	1·69	1·46	1·92

(Above values in inches.)

(c) Block Pair Means.

1.	2.	3.	4.	Standard Error.	Difference for Significance.
2·65	2·51	3·47	4·03	± 0·29	0·87

Legend for Above.

% H_2SO_4	% As_2O_5	% H_2SO_4	% As_2O_5
A.—2·50	.. 0·5	K.—2·50	.. 2·0
B.—3·53	.. 0·5	L.—3·53	.. 2·0
C.—5·00	.. 0·5	M.—5·00	.. 2·0
D.—7·07	.. 0·5	N.—7·07	.. 2·0
E.—10·0	.. 0·5	O.—10·0	.. 2·0
F.—2·50	.. 1·0	P.—2·50	.. 4·0
G.—3·53	.. 1·0	Q.—3·53	.. 4·0
H.—5·00	.. 1·0	R.—5·00	.. 4·0
I.—7·07	.. 1·0	S.—7·07	.. 4·0
J.—10·0	.. 1·0	T.—10·0	.. 4·0

(*c*) *Toxicity Trials.*

Spraying for the 1938 series was done from 7.15 p.m. to 8.45 p.m. on the 7th October. This period was chosen to obviate the influence of time of day—in a previous experiment (3) there was no significant difference between the 7.15 p.m. and 9.15 p.m. applications. The upper layers of the soil were fairly dry, and the weather was generally calm, with occasional gusts of wind. There were twelve replications of each of eleven treatments; the selected plants were just beginning to develop a stem.

The main penetrating agent for the arsenicals was 5 per cent. ammonium thiocyanate. In some instances the arsenical spray solution was acid, in others alkaline. It is not considered that slight differences in acidity would have any appreciable effect (3, p. 16). The original intention was to apply all the arsenicals at the same concentration of the arsenic (0·38 per cent. As.). The hydration of the arsenic pentoxide prevented this.

A summary of the statistical analysis of the results is given in Table 3. Differences between certain treatments are highly significant. The analysis of variance was done on values of log $(1 + x)$, since the errors for this transformation were found to be not significantly non-normal or heterogeneous.

TABLE 3.—MEAN VALUES—1938 TOXICITY TRIAL.

——	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	Difference for Significance.
Actual observations ..	10·0	8·9	8·6	7·3	3·4	1·2	0·5	0·7	1·6	6·7	5·0	..
Log $(1 + x)$	1·00	0·93	0·95	0·90	0·57	0·28	0·10	0·25	0·24	0·83	0·74	0·06

(x = actual observation.)

Legend for Above.

A.—0·49 p.c. As_2O_5, 0·28 p.c. NaOH, 5·0 p.c. NH_4CNS.
B.—0·49 p.c. As_2O_5, 0·28 p.c. NaOH, 5·0 p.c. NH_4CNS, 0·025 p.c. wetter.
C.—0·49 p.c. As_2O_5, 0·50 p.c. triethanolamine, 5·0 p.c. NH_4CNS.
D.—0·50 p.c. As_2O_3, 0·28 p.c. NaOH, 5·0 p.c. NH_4CNS, 0·025 p.c. wetter.
E.—0·70 p.c. dimethyl arsinic acid, 0·28 p.c. NaOH, 5·0 p.c. NH_4CNS, 0·025 p.c. wetter.
F.—1·09 p.c. p-tolyl arsonic acid, 0·28 p.c. NaOH, 5·0 p.c. NH_4CNS, 0·025 p.c. wetter.
G.—1·09 p.c. o-tolyl arsonic acid, 0·28 p.c. NaOH, 5·0 p.c. NH_4CNS, 0·025 p.c. wetter.
H.—1·24 p.c. o-carboxy phenyl arsonic acid, 0·28 p.c. NaOH, 5·0 p.c. NH_4CNS, 0·025 p.c. wetter.
I.—0·82 p.c. sodium methyl arsonate, 0·28 p.c. NaOH, 5·0 p.c. NH_4CNS, 0·025 p.c. wetter.
J.—10 p.c. $NaClO_3$, 0·025 p.c. wetter.
K.—10 p.c. "Sinox",* 0·025 p.c. wetter.

(The "wetter" used was sodium lauryl sulphate.)

* "Sinox" consists of 30 per cent. sodium dinitro-ortho-cresylate, 70 per cent. water.

Spraying for the 1939 trial took place from 4.45 p.m. to 5.30 p.m. on the 26th October. The sky was overcast during the later applications; comments on the soil moisture have already been made (p. 155). Each treatment was replicated twelve times. All the applications of one treatment were made before changing to another. The alphabetical order of the spray treatments is the order in which they were applied. Differences in time of application introduced no errors, because the eleven treatments could be split up into four series. The sprayed plants were excavated on the 7th and 8th November.

The results were not very satisfactory for statistical analysis, because there were large differences in the ranges of variability in different treatments. This could not be rectified by any simple mathematical transformation. Four of the treatments (indicated by an asterisk in Table 4) were therefore omitted from the analysis of variance: it was apparent from inspection that the values for "E" were much higher than those for any other treatment; the values for the three other treatments omitted were nearly zero. Table 4 summarizes the analysis of variance of the remaining seven treatments, and also gives the values for the treatment means. It will be seen that there is a significant difference between some of the treatments.

TABLE 4.—ANALYSIS OF VARIANCE—1939 TOXICITY TRIALS.

Source.	*D. of F.*	*Sum of Sq.*	*Mean Sq.*	*F.*
Treatment ..	6 ..	153·61 ..	25·60 ..	21·51
Block	11 ..	15·21 ..	1·83 ..	—
Error	64 ..	76·39 ..	1·19 ..	—
Total ..	81 ..	245·21 ..	— ..	—

(Treatment term highly significant, $P < 0·001$.)

TABLE OF TREATMENT MEANS.

E*.	B.	C.	A.	K.	H.	I.	J.	D*.	F*.	G*.	Difference for Significance.
12·7	4·4	3·7	2·6	1·7	1·2	0·7	0·7	0·3	0·3	0·1	0·93

(* Difference for Significance not applicable.)

Legend for Above.

A.—8·0 p.c. NH_4CNS, 0·86 p.c. As_2O_5, 0·25 p.c. NaOH, 0·025 p.c. wetter (sodium lauryl sulphate).
B.—8·0 p.c. NH_4CNS, 1·00 p.c. As_2O_5, 0·25 p.c. NaOH, 0·025 p.c. wetter.
C.—8·0 p.c. NH_4CNS, 1·00 p.c. As_2O_5, 0·67 p.c. diethanolamine, 0·025 p.c. wetter.
D.—8·0 p.c. NH_4CNS, 5 p.c. Na_2S, 1·0 p.c. NaOH, 0·025 p.c. wetter.
E.—7·5 p.c. As_2O_5.
F.—Kerosene (B.P. range 170°–270°C., unsaturated content 10–12 p.c.).
G.—Kerosene + 0·01 p.c. lead tetraethyl.
H.—Tar oil, fraction 230°–250°C. (tar acid free).
I.—Tar oil, fraction 210°–230°C. (straight distillate).
J.—Tar oil, fraction 170°–210°C. (straight distillate).
K.—Tar xylenols (210°–230°C.).

3. Discussions and Conclusions.

(a) The Time Factor.

That the length of the subterranean axis killed was greater 10 days than four days after spraying may be explained in two ways. Either, during the six extra days the pentoxide was slowly translocated further downwards, killing more of the axis, or the pentoxide was rapidly translocated downwards after being applied to the leaves, but as its concentration diminished with distance (2) it required a longer time interval to kill the axis at the lower depths. The second explanation is considered the more probable. The concentration of arsenic in the axis of such sprayed plants is very low. Moreover, it has yet to be proved that arsenic pentoxide, applied with a strongly acid penetrating agent, is translocated to any extent as a result of metabolic activities (see below).

(b) Optimal Concentrations.

The data in Table 2 show that the length of the axis killed was increased by increasing the concentration of the pentoxide and by decreasing the concentration of acid. Perhaps a greater length would have been killed if no acid had been used and the concentration of pentoxide had been increased to more than 4 per cent. In fact, in the 1939 toxicity trial, made on the same day, 7·5 per cent. aqueous arsenic pentoxide killed four plants to a depth exceeding 19 inches.

Different results might have been obtained if the soil had been dry at the time of spraying. The general poorness of these results for acid arsenicals is attributed to the high moisture content of the soil.

(c) Toxicity Trials.

Comparison of the toxicity of different poisons may be made if they are applied at equimolecular or similar concentrations, but not if applied at widely differing concentrations or with very different wetting or penetrating agents. In the latter instances the effectiveness of the different sprays may be compared.

According to Table 3, arsenic pentoxide or trioxide with ammonium thiocyanate gave more effective spray solutions than 10 per cent. sodium chlorate or "Sinox".* The chlorate spray was more effective than the "Sinox" spray; also, the effectiveness of an arsenic pentoxide-ammonium thiocyanate spray (A) was reduced by a small but significant amount on including a wetting agent (B).

In the series of arsenical compounds the toxicity of arsenic pentoxide was not increased by the inclusion of a surface-active base such as triethanolamine. Arsenic pentoxide was probably more toxic than the trioxide, but not definitely so. The pentoxide and trioxide were significantly more toxic than the organic arsenicals; this confirms some earlier results (3). Dimethyl arsinic acid was significantly more toxic than *p*-tolyl arsonic acid, *o*-carboxy phenyl arsonic acid, or sodium methyl arsonate (the last three showed practically the same remote toxicity). It is interesting to note that the *p*-tolyl arsonic acid was considerably more toxic than its ortho-isomer.

* These comments about toxicity or effectiveness refer to the results observed 11–13 days after spraying. Sodium chlorate, e.g., may be very slow in action.

In the 1939 trials, the eleven spray solutions can be divided into four groups—(1) arsenic pentoxide, (2) arsenical solutions containing ammonium thiocyanate, (3) sodium sulphide, also kerosene and its solution of lead tetraethyl, (4) the coal tar distillates. Arsenic pentoxide, at 7·5 per cent., gave outstanding results. The inclusion of diethanolamine, another surface-active base, did not increase the toxicity of the pentoxide. Arsenic pentoxide, at an equivalent concentration of arsenic, was significantly more toxic (in the "remote" sense) than the trioxide.

Sodium sulphide with ammonium thiocyanate gave no promise as a herbicide; this is of interest because hydrogen sulphide is highly toxic to plants. Kerosene, and its solution of lead tetraethyl, gave very poor results. It is possible that the lead tetraethyl would have been more effective at higher concentrations. This failure of kerosene is noteworthy because it has been recommended for the control of dandelions (4), a related species.

Of the coal tar fractions, the xylenol fraction was the most effective. This is in accord with the results reported for jointed cactus (5). However, xylenols are very toxic to the latter species, whereas they are only slightly so to skeleton weed. A substance distinctly toxic to one species may not therefore be so to another.

A Note on the Translocation of Poisons.

Some comments on the methods by which a poison may be translocated within a plant have already been given (3, pp. 13, 38). The general opinion has been that the downward translocation of inorganic compounds of arsenic depends upon the water deficit obtaining at the time of spraying. This opinion was held when commencing investigations on skeleton weed in 1936. The 1939 toxicity trial, however, shows that the translocation of inorganic arsenic may occur as a result of metabolic activities.

If the spray solution contains a high concentration of a strong acid, translocation depends upon the existence of a water deficit. Proof is afforded by the fact that the best results for acid arsenicals applied to skeleton weed have been obtained when the soil is dry; additional proof is offered by the time-of-day experiment (3). But if the spray solution contains only arsenic pentoxide, the translocation downward does not depend solely upon a water deficit, i.e., it depends at least in part upon some metabolic activities. Proof of this is afforded by the following:—The soil was very moist at the time of spraying on the 26th October, 1939, the sky was overcast, and throughout the day any variations in water deficit were not large enough to be macroscopically visible. Using Thoday's turgidity technique (6), it was not possible during that day to observe any changes in turgidity (or conversely, water deficit) in the leaves of skeleton weed.

The increase in effectiveness of the acid arsenical on increasing the concentration of arsenic pentoxide, and on decreasing the concentration of sulphuric acid (Table 2) may be due to the translocation of the arsenic by metabolic activities becoming more and more effective as the concentration of arsenic is increased and the concentration of acid reduced.

4. Acknowledgments.

The experiments were done at the Wagga Experiment Farm, Bomen, N.S.W., through the courtesy of the manager, Mr. A. J. Pinn. The organic arsenicals were kindly supplied by Mr. G. J. Burrows, of the Department of Chemistry, Sydney University.

The statistical analysis of the experimental data was done by Miss F. E. Allan, to whom thanks are also due for invaluable aid in designing the experiments.

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The Mineragraphic Investigation of Mill Products of Lead-Zinc Ores.

By F. L. Stillwell, D.Sc. and A. B. Edwards, B.Sc., Ph.D.**

Summary.

The preparation of mill products for mineragraphic examination and a quantitative method of expressing the results of the examination based on mineral counts of sized fractions are described. The quantitative method yields a picture of the distribution and association of the valuable minerals at any stage of the procedure in an ore-dressing mill. Its application to lead concentrates and tailings is illustrated and its value demonstrated in specific instances.

1. Introduction.

Lead-zinc ores are complex mineral aggregates in which three or more valuable minerals containing chiefly lead, zinc, and silver are intimately associated with each other and with other minerals which are valueless. The aim of milling these ores is to separate and concentrate the valuable minerals into marketable products as lead concentrates and zinc concentrates. Mineragraphic examinations of the crushed ore at the many and various stages in its passage through

* An officer of the Council engaged on mineragraphic investigations and accommodated at the Geology School, University of Melbourne.

the mill can be made to yield a picture of the changing distribution of the valuable minerals and their combinations. A series of such pictures enables one to follow the progress of an individual mineral through the mill, revealing the nature and type of the contaminating minerals in the final products and the nature of the losses that occur in the tailings.

These examinations have been found to throw considerable light on the efficacy or otherwise of the crushing treatment practised, enabling the mill operator to determine whether losses in recovery arise from the incomplete freeing of the valuable minerals during crushing or to the ineffectiveness of the flotation practice. Where losses are found to arise from the incomplete liberation of the valuable minerals by crushing, it enables him to decide whether finer grinding is economically possible and provides some guide as to the stage in the mill treatment at which finer grinding could most profitably be introduced. It also indicates the fineness of grinding that must be attained before the maximum freeing of the valuable minerals can be obtained.

Clearly, therefore, such examinations should precede any attempt to improve milling practices, because they give the mill operator a mineral picture at each stage in the existing treatment, and when the picture is interpreted with the aid of assays, it may indicate what steps and care should be taken towards improvement. During experimental ore dressing, such information would be particularly valuable; at a still earlier stage, examination of the untreated ore as to nature and grain size of the valuable minerals, and their manner of association, provides useful information to guide subsequent preliminary ore-dressing investigations.

2. Technique.

The preparation of mill products for mineragraphic examination involves (1) sizing, (2) briquetting, and (3) polishing.

(*a*) *Sizing.*

Crushed ore consists of grains of all sizes between the maximum and the finest dust, and, before any comparison can be made between the individual types of grains, it is necessary to prepare samples of approximately equal grain size, i.e., to size the material. With coarse-grained ores, such as those at Broken Hill, it is possible to obtain a number of fractions by sieving with screens of varying mesh. Although it is possible to manufacture laboratory screens of 400 mesh (aperture 37 microns), for all practical purposes the limit of good sizing by screens is about 200 mesh (aperture 76 microns). Milling technique, however, often calls for superfine grinding, so that the crushed ore is frequently too fine to be closely sized with wire screens. It is, therefore, necessary to use an elutriation method for material finer than 200 mesh, and the most recently developed apparatus for the purpose is the Haultain Infrasizer. This machine is an air elutriator with outstanding advantages, and its advent has greatly facilitated the extension of mineragraphic work and of milling investigations in general.

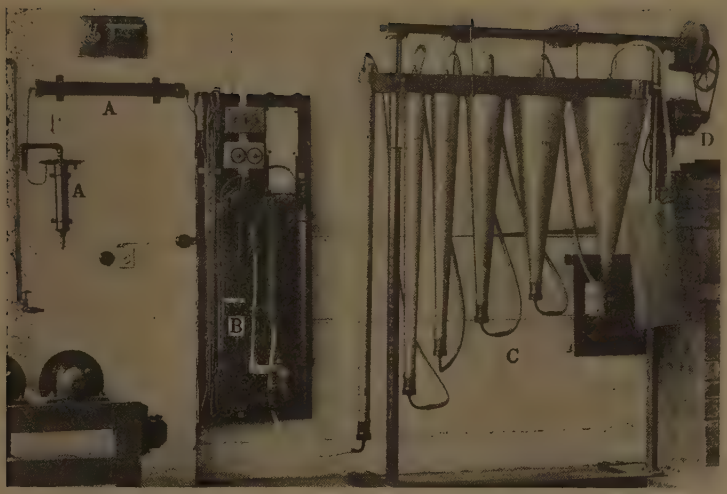


FIG. 1.—Haultain Infrasizer. Compressed air enters through two filters (A), passes through the control board (B) to the series of tubes (C), which are periodically shaken by a device operated by motor (D) to prevent particles adhering to the sides of the tubes.

The Haultain Infrasizer in the Melbourne Ore Dressing Laboratory (Fig. 1) consists of six tubes, the smallest being 3·5 inches in diameter and the largest 20 inches. They are connected and operate in series, and the sample to be sized is placed in the smallest tube. Air, filtered and automatically controlled as to pressure and volume, is blown in at the bottom of the smallest tube, passing from the top of one tube to the bottom of the next. The maximum diameter of the tubes varies as the square root of 2, so that the velocity of the air is halved in each succeeding tube. Each tube thus collects a fraction of particles having equal settling rates which are half speed in relation to those in the preceding tube. With a feed of solid particles of equal density and surface tension, all perfectly spherical, a series of Haultain tubes would collect fractions decreasing in diameter by the square root of 2.

Seven fractions can thus be recovered, one from each tube, and one from a dust-collecting bag placed after the largest tube. The nominal micron sizes for quartz are 56, 56-40, 40-28, 28-20, 20-14, 14-10, and −10. Emphasis has to be placed on "nominal," because of the impossibility of accurately measuring the average diameter of irregular angular particles and because the actual size varies with the density of each particular mineral. However, each particle in a fraction should have approximately the same weight.

The advantage of this air elutriator over a laboratory water elutriator is that it produces a sized fraction big enough for assay in addition to microscopical examination. The treatment is more rapid than in a water elutriator and, being a dry process, the settling and drying of the products are obviated. Further, the sample is produced without highly skilled manipulation because, given a steady air supply,

the infrasizer may be left more or less unattended, and in fact may be left to run overnight. Large samples of 600 grammes are commonly run overnight, while small samples are given two to three hours' running time. When a run is completed, the fractions are collected and weighed and, as the –10 micron fraction is frequently not retained and, when retained, is always subject to a small unavoidable loss, its amount is determined by difference. Each sized fraction is then assayed.

(*b*) *Briquetting.*

Fractions for microscopical examination are prepared for polishing by mixing a representative portion with bakelite powder and converting the mixture into a solid briquette in a briquetting press. In this, the powder is subjected to a pressure of 2 tons per square inch at a temperature of about 140°C. for a period of four minutes. A briquette, circular in section and 1 inch in diameter, is thus prepared in a press built at the Melbourne University and previously described in detail.*

Briquetting and subsequent microscopical examination have been arbitrarily limited to the four coarser fractions obtained from the Haultain Infrasizer. This achieves a reduction in labour without materially affecting the results, because the trends of mineral changes in the finest fractions are indicated by the assays coupled with the trends in the coarser fractions.

(*c*) *Polishing.*

The surface of the briquette is ground true with very fine carborundum and then polished in two stages on lead laps, which revolve at the comparatively slow rate of 60 revolutions per minute. The specimen is held in contact with the lead lap by a mechanical holder which rotates in the opposite direction to the lead laps at a speed of 200 revolutions per minute. The abrasive in the first stage is very fine optical emery, and in the second stage calcined magnesia. A polish equal to or superior to that on massive ore can be readily obtained, particularly when in the second stage an abundance of oil and magnesia is used.

3. Microscopic Method.

The polished briquettes are examined under the reflecting microscope, and all minerals are identified by their colour, hardness, effect on polarised light, and, if necessary, by etching tests. A systematic series of traverses is then made across the polished section, during which every grain that passes across the centre of the field is counted and its mineral composition, whether free or composite, noted. Experience has shown that for most products a count of 1,200–1,500 grains taken along traverses 1 mm. apart over the surface of the briquette provides a representative sample. Larger counts will not yield much variation in the important constituents, but may show a wider variation among the rarer combinations of minerals. The count of the various mineral types is then converted to percentages for ease of comparison. As the following examples show, this provides a ready picture of the mineral association in any product and a basis of comparison of one fraction with another fraction of the same product.

* Stillwell F. L. (1933).—Bakelite Press for Mounting Grains and Ores. *Proc. Aʻasian Inst. Min. and Met.*, n.s., No. 90, pp. 237-246.

A comparison between the assay figures and the grain percentages of a number of fractions of a mill product will reveal accurately the trend towards separation induced by grinding; yet it must be emphasized that grain percentages arrived at in this manner do not have the accuracy of assay figures, and they are subject to both inherent and personal errors.

The fact that mineral grains are three-dimensional, whereas they are observed on a two-dimensional surface, means that certain composite grains must appear to the observer as free grains since, in some instances, the section will cut through only one component of the composite grain. This error in observation remains uncompensated, since the free grains can never appear composite. There will thus be a slight over-estimation of the proportion of free grains and a corresponding under-estimation of the proportion of composite grains. This error will be directly related to the number of composite grains present, and, as the proportion of these decrease in the finer fractions, will become increasingly small. While this error makes it unsafe to rely too fully upon the percentage figures as an accurate measure of grinding efficiency, it does not prevent a reliable comparison of related mill products, since, with a given grinding, the inherent error will tend to be constant for each mill product.

Experience has shown that a personal error may also enter into the counting, as, for example, in estimating whether a minute inclusion of one mineral in another is of sufficient size for the grain to be called composite. This personal error has the effect that, while counts of the same set of polished briquettes of a particular mill product by different investigators will show the same trends of increasing freeing of the particles with decreasing grain size, there tends to be a small, but more or less constant, difference in the actual percentages obtained. This error tends to remain constant when the various fractions of a single mill product are measured by the same investigator and becomes negligible in the comparison of the mineral composition of the fractions.

4. Application to Concentrates.

The results obtained by this method are illustrated by the following four tables, illustrating four lead concentrates. These four examples are isolated instances removed from their setting among associated mill products, but they serve to show the nature of the information that is obtained.

Table 1 illustrates the mineral composition of a lead concentrate derived from a coarse-grained ore and prepared by flotation from a slime product after the coarse grains have been removed. The various types of grains are quantitatively expressed in a detailed statement, while the outstanding features are shown in a summarized table. In this case, a small fraction of the concentrate is retained on a 200 mesh screen, and the remainder has been sized in the Haultain Infrasizer. The results show that most of the lead in the small coarse fraction is due to composite grains containing galena, which rapidly decrease in number with finer crushing. All other fractions consist very largely of free galena and free blende in approximately equal amounts. The concentrate is thus highly contaminated by free blende, and it is revealed that the flotation practice adopted has made an unsatisfactory separation of the zinc mineral from the lead mineral.

Table 2 illustrates a lead concentrate prepared from a fine-grained ore which has been finely ground. In this case, the four coarser fractions from the Haultain Infrasizer comprise only 49 per cent. of the original sample. The lead grade of this concentrate in these four sizings is low and comparable with that of the preceding example. The statement of the mineral composition shows that this is due to the large number of composite particles containing galena, 42·5 per cent. in the coarse fraction and 20·5 per cent. in the finest fraction, and it is a result of the small size of many galena particles. Hence the problem of improving the grade of this concentrate is not one of flotation, but is still one of fine grinding and classification of the ore, notwithstanding the finely ground character of the sample.

Table 3 illustrates a lead concentrate, similar in grade and type to the second example. Further, it has been prepared from a similar type of ore which, while geologically and mineralogically similar in occurrence, consistently yields poorer recoveries. The problem in this case was to define the differences between the two batches of ore from which the concentrates represented by Tables 2 and 3 were obtained. An outstanding feature of the concentrate is the large proportion of composite grains containing galena, amounting to more than half of the two coarser fractions and to nearly half of the two finer fractions. The fact that these composite grains are so numerous even in the finest fraction signifies the small size of many of the galena particles which remain attached to blende and pyrite. Comparing the percentages of "free galena" and "galena composites" in the summarized statement with the corresponding percentages in Table 2, it will be seen that the proportion of grains of free galena to those containing combined galena is much smaller in this concentrate. As this difference is repeated in each sizing, while the total amount of lead, as shown by assay, is similar, the difference must arise from an inherent characteristic of the ore, and not from variations in grade or time or degree of crushing. Hence the ore from which this concentrate was produced is finer grained than the ore from which the preceding sample was produced. Simple visual examination of the ore would not detect this slight difference in grain size which so significantly affects the mill treatment. It is thus an example of the general case that the difficulties of treatment are greatly increased with the fineness of grain of the valuable mineral. The relative sizes and appearance of the four fractions are shown in Figs. 2–5.

Table 4 is an example of a lead scavenger concentrate. When the ore pulp passes successively through a series of eight flotation cells, the product of the first four cells is retained for the preparation of a final lead concentrate, while the product of the last four cells, called a lead scavenger concentrate, removes the lead from the tailing, which passes on to the zinc flotation unit. The lead scavenger concentrate is returned to the grinding circuit before again passing through the lead flotation cells. The example, illustrated in Table 4, was obtained from a coarse-grained ore, and the fractions were obtained by sieving. These fractions comprise only half the product and, as the Haultain Infrasizer was not used, the remaining half is excluded from the picture. Yet sufficient has been done to make it clear why this lead concentrate has escaped through the first four flotation cells. It is revealed that the

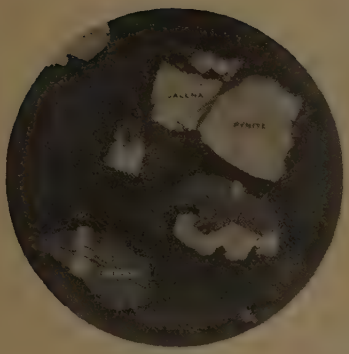


FIG. 2.

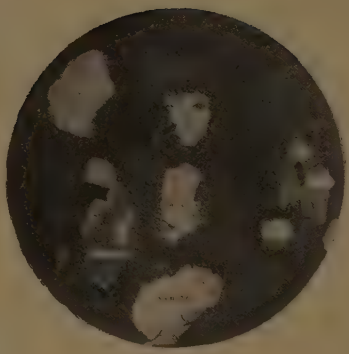


FIG. 3.

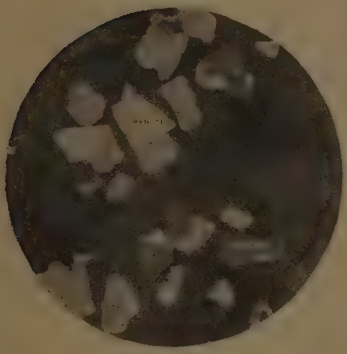


FIG. 4.

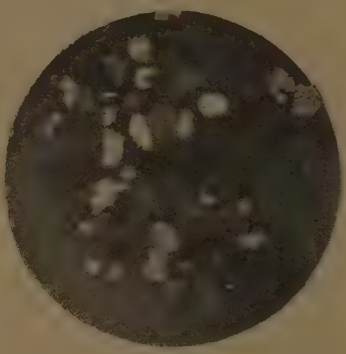


FIG. 5.

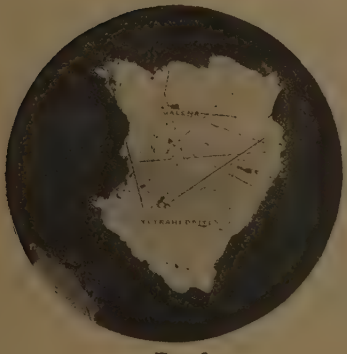


FIG. 6.

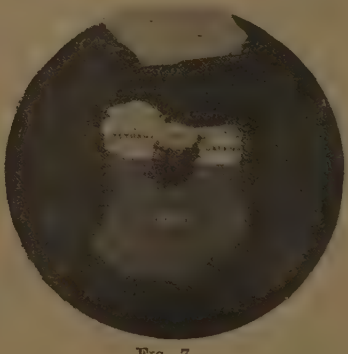


FIG. 7.

FIGS. 2, 3, 4, 5.—Polished sections of the + 56, 56-40, 40 28, and 28 20 micron fractions, prepared by the Haultain Infrasizer, of the lead concentrate of Table 3. Mag. 260.

FIG. 6.—A composite grain of galena and tetrahedrite recovered from a final tailing. Mag. 60.

FIG. 7.—A composite grain of blende, galena, and tetrahedrite recovered from a final tailing. Mag. 185.

lead content is dominated by a high proportion of composite grains of galena. Other interesting features are that the coarse fraction has a high dilution of gangue particles, which is replaced in the fine fraction by a high dilution with free blende particles, and that the variation of free galena is reflected in the lead assays.

TABLE 1.—LEAD CONCENTRATES.

Sizing Analysis.

Size	+ 200 mesh or + 70μ	+ 56μ	56–40μ	40–28μ	28–20μ	20–14μ	14–10μ	— 10μ
Percentage weight	1·4	nr.	11·25	17·15	16·15	13·8	9·7	30·55
Assay of Fractions—								
Pb .. .. %	n.d.	..	45·2	48·6	47·5	45·8	44·9	..
Zn .. .. %	n.d.	..	26·4	24·5	23·5	21·3	21·2	..

Mineral Composition.

Constituents.	+ 70μ.	56–40μ.	40–28μ.	28–20μ.
Galena	3·3	41·8	43·5	46·5
Galena-blende	11·3	9·8	5·1	3·2
Galena-gangue	5·2	1·3	·4	·4
Galena-chalcopyrite	..	·2	·1	·1
Galena-blende-gangue	1·6	·1	·3	..
Galena-blende-pyrrhotite	·2	·1	..	..
Galena-blende-chalcopyrite	·7	·1	·1	..
Galena-chalcopyrite-gangue	·2	..	..	..
Blende	43·9	38·8	42·1	42·6
Blende-chalcopyrite	5·1	·9	·6	·5
Blende-gangue	·8	·4	·9	·2
Blende-pyrrhotite	·3	·1	..	·1
Blende-chalcopyrite-gangue	·2	..	..	..
Blende-chalcopyrite-chalcostibite ..	·2	..	..	..
Blende-pyrrhotite-gangue	·1	..	..	..
Chalcopyrite	7·7	1·8	1·3	1·5
Pyrrhotite, &c.	·1	1·1	·3	·5
Chalcopyrite-gangue	·6	·2	..	..
Chalcopyrite-pyrrhotite	·2	..	..	..
Gangue	12·4	2·0	4·1	3·6
Gangue-pyrargyrite	·1	..	..	..
Tetrahedrite	3·6	·7	·7	·7
Tetrahedrite-galena	·2	·5	·3	·1
Tetrahedrite-blende	·8	·1	·1	..
Tetrahedrite-chalcopyrite	·2	..	..	..
Tetrahedrite-gangue	·1	..	..	..
Tetrahedrite-galena-blende	·3	..	·1	..
Tetrahedrite-blende-chalcopyrite ..	·3	..	..	..
Tetrahedrite-blende-pyrrhotite	·1	..	..	..
Tetrahedrite-galena-blende-gangue ..	·2	..	..	..
Total	100·0	100·0	100·0	100·0
Number of grains ..	1,200	1,700	1,700	1,700
Summarized Mineral Composition—				
Galena	3·3	41·8	43·5	46·5
Galena composites	19·2	11·6	6·0	3·7
Blende	43·9	38·8	42·1	42·6
Blende composites (*ex* galena)	6·7	1·4	1·5	·8
Chalcopyrite	7·7	1·8	1·3	1·5
Tetrahedrite (grains and composites) ..	5·8	1·3	1·2	·8
Other grains	13·4	3·3	4·4	4·1
Total	100·0	100·0	100·0	100·0

Table 2.—Lead Concentrates.

Sizing Analysis.

Size	+ 56μ	56–40μ	40–28μ	28–20μ	20–14μ	14–10μ	– 10μ
Percentage weight	1·8	11·9	18·0	17·4	14·3	10·7	25·9
Assays—							
Pb .. %	47·0	40·8	42·2	44·0	48·6	53·0	62·4
Zn .. %	7·6	11·6	14·0	14·2	12·6	10·2	5·6

Mineral Composition.

Constituents.	+ 56μ.	56–40μ.	40–28μ.	28–20μ.
Galena	25·9	31·1	35·6	40·1
Galena-blende	16·2	16·8	21·3	17·2
Galena-pyrite	15·1	7·5	4·2	2·1
Galena-chalcopyrite	1·7	1·5	2·1	·7
Galena-gangue	..	1·0	·4	..
Galena-blende-pyrite	6·1	3·0	1·4	·1
Galena-blende-chalcopyrite	1·0	·5	·4	·2
Galena-blende-gangue	·1	·2	..	..
Galena-pyrite-chalcopyrite	·6	·4	..	..
Galena-blende-pyrite-chalcopyrite ..	·4	·2	·1	..
Galena-blende-pyrite-gangue	..	·3	..	..
Blende	1·3	4·9	7·1	13·3
Blende-pyrite	3·7	1·6	1·2	·9
Blende-chalcopyrite	·1	·6	·9	·7
Blende-gangue	..	·4	·4	·1
Blende-pyrite-chalcopyrite	·1	..	·1	·1
Chalcopyrite	3·6	5·9	9·4	12·1
Pyrite	17·9	19·1	12·0	10·4
Gangue	1·1	1·6	·8	·4
Chalcopyrite-pyrite	·6	·2	·4	}
Chalcopyrite-gangue	·1	·4	..	·2
Pyrite-gangue	·3	·4	·1	}
Tetrahedrite	2·0	1·5	1·2	1·1
Tetrahedrite-galena or blende	1·4	·8	·6	·2
Tetrahedrite-pyrite or chalcopyrite ..	·7	·1	·3	·1
Total	100·0	100·0	100·0	100·0
Number of grains counted	704	1,008	1,800	1,600
Summarized Mineral Composition—				
Galena	25·9	31·1	35·6	40·1
Galena-composites	42·6	32·2	30·5	20·5
Blende	1·3	4·9	7·1	13·3
Blende composites (*ex* galena)	3·9	2·6	2·6	1·8
Chalcopyrite	3·6	5·9	9·4	12·1
Other grains	22·7	23·3	14·8	12·2
Total	100·0	100·0	100·0	100·0

Table 3.—Lead Concentrate.

Sizing Analysis.

Size	+ 56μ	56–40μ	40–28μ	28–20μ	20–14μ	14–10μ	– 10μ
Percentage weight	·2	4·7	13·2	18·9	18·4	14·9	29·7
Assay of Fractions—							
Pb .. %	..	45·8	42·0	41·8	44·6	48·6	..
Zn .. %	..	13·2	18·4	21·0	20·6	20·6	..
Fe .. %	..	11·6	10·8	8·4	6·0	6·2	..

Mineral Composition.

Constituents.	+ 56μ.	56–40μ.	40–28μ.	28–20μ.
Galena	29·0	25·0	26·7	30·6
Galena-blende	21·7	23·7	23·8	33·0
Galena-pyrite	10·6	8·0	4·0	1·9
Galena-chalcopyrite	2·1	1·2	·7	·7
Galena-gangue	·4	1·0	1·0	·4
Galena-blende-pyrite	15·3	6·8	2·5	1·1
Galena-blende-chalcopyrite	·7	·7	·5	·2
Galena-blende-gangue	1·6	7·9	13·9	4·4
Galena-pyrite-chalcopyrite	·1	·2	..	·1
Galena-pyrite-gangue	·7	·6	·4	·5
Galena-chalcopyrite-gangue	·1	·3	·2	·1
Galena-blende-pyrite-gangue	4·2	3·7	1·7	·6
Galena-blende-pyrite-chalcopyrite	·2	·1	·1	·1
Galena-blende-chalcopyrite-gangue	..	·1	·1	·2
Blende	1·0	1·6	3·8	9·5
Blende-pyrite	2·8	3·2	2·5	1·3
Blende-chalcopyrite	·1	·2	·3	·2
Blende-gangue	..	1·1	1·8	2·4
Blende-pyrite-gangue	·4	1·8	1·0	·4
Blende-pyrite-chalcopyrite	·1	·2	·1	..
Blende-pyrite-chalcopyrite-gangue	·1	..	..	..
Chalcopyrite	·3	1·2	2·3	3·7
Pyrite	6·4	9·6	9·1	6·6
Gangue	·7	·6	·3	·1
Pyrite-chalcopyrite	·4	·3	1·1	·5
Pyrite-gangue	·5	·7	1·7	·8
Chalcopyrite-gangue	·1	..	·1	·1
Tetrahedrite composites	·4	·2	·3	·5
Totals	100·0	100·0	100·0	100·0
Number of grains counted	1,400	1,600	1,500	1,700
Summarized Mineral Composition—				
Galena	29·0	25·0	26·7	30·6
Galena composites	58·0	54·4	49·1	43·6
Blende	1·0	1·6	3·8	9·5
Blende composites (*ex* galena)	3·6	6·6	5·7	4·4
Chalcopyrite	·3	1·2	2·3	3·7
Other grains	8·1	11·2	12·4	8·2
Totals	100·0	100·0	100·0	100·0

Table 4.—Lead Scavenger Concentrate.

Sizing Analysis.

Size	+ 40 mesh	+ 60	+ 80	+ 120	+ 200	− 200
Percentage weight	·2	2·0	6·2	14·1	28·9	48·6
Assays—						
Pb %	..	24·4	31·8	27·2	18·0	19·0
Zn %	..	18·4	23·8	26·8	32·3	30·4
Ag oz.	..	11·6	10·6	8·4	6·2	6·6

Mineral Composition.

Constituents.	+ 60	+ 80	+ 120	+ 200
Galena	9·6	13·9	12·1	8·0
Galena-blende	19·1	28·7	34·4	26·1
Galena-pyrrhotite	..	·2	·3	·1
Galena-gangue	10·8	10·5	11·0	9·7
Galena-chalcopyrite	..	..	·3	·1
Blende	15·1	21·2	22·6	35·4
Blende-chalcopyrite	1·7	2·0	1·0	1·6
Blende-pyrrhotite	·2	·1	·2	..
Blende-gangue	1·9	1·1	1·0	1·5
Chalcopyrite	2·5	2·6	1·6	1·0
Chalcopyrite with pyrrhotite or gangue	1·5	·8	·8	·8
Tetrahedrite	·2	·1	..	..
Tetrahedrite-galena	..	·2	·1	..
Tetrahedrite-blende	·2	·2	·3	·4
Tetrahedrite-chalcopyrite	..	..	..	·2
Tetrahedrite with two components	1·7	·2	1·2	·5
Arsenopyrite	·4	..	·2	·4
Pyrrhotite	·2	..	·3	·8
Gangue	31·5	14·5	9·0	10·5
Three or four-component grains containing galena and blende	3·2	3·5	3·6	2·9
Totals	100·0	100·0	100·0	100·0
Number of grain counted	529	883	1,137	1,036
Summarized Mineral Composition—				
Galena	9·6	13·9	12·1	8·0
Galena composites	33·1	42·9	49·6	38·9
Blende	15·1	21·2	22·6	35·4
Blende composites	3·8	3·2	2·2	3·1
Chalcopyrite	2·5	2·6	1·6	1·0
Tetrahedrite (grains and composites)	2·3	·9	1·6	1·1
Other grains	33·6	15·3	10·3	12·5
Totals	100·0	100·0	100·0	100·0

5. Application to Tailings.

A similar type of examination can be applied to the study of tailing losses and so indicate whether such losses are due to incomplete liberation of valuable minerals during grinding, or possibly to incomplete flotation of free grains. Where the losses occur in composite grains, microscopic examination may reveal whether finer grinding might release the valuable minerals or whether they occur in particles so small as to be beyond recovery.

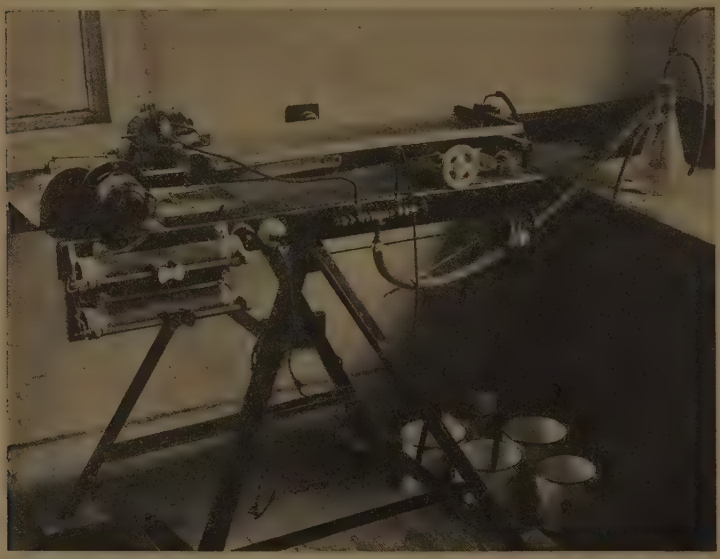


FIG. 8.—Haultain Superpanner, fitted with electric motors and resistances.

The amounts of the valuable minerals in the tailings are usually so small that it is necessary, after sizing and before briquetting, to prepare concentrations of the valuable minerals. This preparatory step is accomplished by the Haultain superpanner, which, as its name suggests, is a delicately-controlled panning dish. (See Fig. 8.) It is mechanically driven, either by compressed air or by two small ¼-h.p. electric motors, and is subject to eight separate adjustments. The movement of the trough-shaped pan, which is 30 inches long and 10 inches wide, is closely analogous to that of the prospector's panning dish; and the delicate control of the movement, which can be maintained steadily for extended periods, makes it particularly adapted for the concentration of the heavy minerals in a tailing. The model used for these investigations is one of the earliest, and has been described in detail by Dr. A. B. Edwards*. This instrument can give valuable results on as small a quantity of material as one gramme, or will treat much larger amounts. It yields the best results when the samples have previously been sized in the Haultain Infrasizer.

* "The Haultain Superpanner," *Chem. Eng. and Min. Review*, **31**: 502-503, Sept. 10, 1939.

When a charge of lead-zinc mill residues is panned on this instrument, the heavy galena-bearing particles are concentrated at the head of the pan. This "head" is always very small, and often is less than 0·01 gramme in weight. In addition to the galena, it will include other heavy sulphides, such as arsenopyrite, that may be present in the residues. The zinc blende has a much lower specific gravity than galena, and cannot be concentrated so effectively; but it can be retained in a bulkier low-grade product further down the pan. If abundant pyrite is present in the residue, the "head" of galena will be succeeded on the pan by a concentration of pyrite, which is followed, in turn, by zinc blende and then gangue. Sharp separation of the zinc blende from the pyrite on the one hand, or from the gangue on the other, is never obtained because, not only are the differences in specific gravity between them small, but there are also considerable numbers of composite particles of zinc blende intergrown with either pyrite or gangue. Even if pyrite is absent from the residue, the transition from a product rich in zinc-blende to one consisting of clean gangue still remains, and this transition zone must be included with the zinc-rich product, in order to obtain all the zinc-blende. In the treatment of one such residue, where the blende tended to segregate with a heavy gangue mineral that occurred as platy cleavage particles which tended to lie flat on the surface of the pan, a final separation of the more or less equidimensional zinc-blende particles was achieved by causing them to roll down the gently-shaking pan under a stream of water sufficiently slow as not to move the platy gangue particles. This applied, however, only to the coarser fractions of the residue, and effective separations were not always possible with the finer fractions.

The two or three products thus obtained on the superpanner for each sized fraction of the residues, according to its composition, are then removed with a pipette, dried and weighed, so that the proportion of each to the original sample is known. Each is then briquetted, polished, and subjected to microscopical examination in the same way as the concentrates described above.

The following examples show the kind of results that can be obtained.

A final residue from the mill treatment of a lead-zinc ore was sized on the Infrasizer, and the sizings obtained were then assayed, with the results shown in Table 5. Three products, viz., a galena-rich head, a pyritic product, and a blende-rich product, were prepared on the superpanner from each of the four coarser fractions. The systematic investigation of each of these gave the results which are condensed in Table 5, and expressed as percentages of the particular Infrasizer fraction concerned. The results show that the free galena in the heads is insignificant and can account for only a small fraction of the lead loss as shown by the assays. Similarly, the free grains of zinc blende are quite insufficient to account for the zinc loss recorded in the assays. The composite grains containing galena or blende or both must, therefore, contribute largely to the losses in zinc and lead. The assays show that the losses decrease in the finer sizings, and this can be attributed chiefly to the decrease in the number of composite grains in these finer sizings. Finer grinding, if practicable, would therefore reduce the losses; but many of the enclosed particles of galena and blende are probably too small to be liberated even so, and so represent an irreducible loss. The sudden increases in the lead and zinc assays

of the –10 micron sizing fraction must be attributed to causes other than the composite grains, and one such cause is the presence of traces of oxidized lead and zinc minerals in the residue.

In another example of residues from the treatment of lead-zinc ores there was an appreciable loss of silver. In this case composite grains of tetrahedrite were observed in each polished section of each sizing of heads and blende-rich products from the superpanner. In a number of these grains tetrahedrite formed at least a third of the area of the grain, and it became quite clear that the losses in silver were due to losses in silver-bearing tetrahedrite. Two of the composite grains recovered by the superpanner are illustrated in Figs. 6 and 7, from which it may be inferred that losses in lead, zinc, and silver could be reduced by finer grinding.

TABLE 5.—MILL RESIDUES.

Sizing Analysis.

Size	+ 56μ	56–40μ	40–28μ	28–20μ	20–14μ	14–10μ	– 10μ
Percentage weight	19·6	23·0	14·1	9·2	7·1	5·6	21·4
Assays—							
Pb .. %	1·6	1·2	·8	·6	·53	·5	1·6
Zn .. %	3·8	2·8	1·7	1·2	1·15	1·1	2·6

Mineral Composition.

——	+ 56μ.	56–40μ.	40–28μ.	28–20μ.
Heads—				
Galena .. .. .. %	·0155	·0068	·0072	·00096
Galena composites .. .. %	·0029	·0017	·0011	·00005
Pyritic products—				
Pyrite	27·4	36·3	38·4	33·7
Pyrite-blende	6·3	5·3	3·1	1·5
Grains with blende and galena	1·9	1·1	·1	·1
Other grains with galena	1·1	1·4	·8	·4
Other grains with blende	·9	1·3	1·1	·9
Other grains (gangue, &c.)	2·4	2·1	1·6	1·3
Blende-rich products—				
Blende	·084	·030	·079	·027
Blende-gangue	·356	·322	·144	·051
Grains with blende and galena	·216	·067	·019	·003
Other grains with galena	·271	·176	·065	·021
Other grains with blende	·385	·180	·130	·009
Other grains (chiefly gangue)	2·354	2·970	4·217	2·389

The Leaf Hopper *Thamnotettix argentata* Evans, a Vector of Tobacco Yellow Dwarf.

*By G. A. H. Helson, M.Sc.**

Summary.

T. argentata, a vector of tobacco yellow dwarf, breeds on a wide range of host plants. All attempts to breed it on tobacco, however, have failed. Many of the host are common weeds in tobacco fields or grow in the surrounding pastures, and provide a series of hosts on which the insect is able to breed and survive throughout the year, producing three generations in that time in northern Victoria. Adults and late instar nymphs overwinter and begin breeding on capeweed and crowfoot in the spring.

Field observations in Victoria during 1940-41 showed that the vector bred on capeweed and crowfoot and increased to considerable numbers before these weeds died at the end of November. At this time large numbers of nymphs died, and first generation adults, which had reached a peak of abundance and were apparently carrying the virus, were forced on to the young tobacco crop for want of other food. Symptoms of the disease showed up about a fortnight later. The adults fed on the tobacco during November and December untill summer host plants were available. Oviposition began on the young weed seedlings almost as soon as they appeared above the ground and gave rise to the second generation at the end of February. A third and overwintering generation appeared at the end of March.

The life-cycle at four different constant temperatures shows that the maximum value for the zero of development of the incubation period is 13·7°C. and that of the feeding period 12·8°C. The insect breeds readily at temperatures between 22°C. and 28°C.

1. Introduction.

The leaf hopper, *Thamnotettix argentata* Evans, was shown by Hill (1) to be a vector of tobacco yellow dwarf, an important virus disease that occurs mainly in the tobacco-growing districts of New South Wales and Victoria. In order to investigate the alternative host plants of the virus and to develop methods of controlling the disease, it was necessary to study the life-cycle and habits of the vector, and the following is a report of work done from October, 1940, to December, 1941.

2. Method.

The life-cycle was studied with insects reared on potted small-flowered mallow plants† (*Malva parviflora* L.) enclosed in 7-in. lamp glasses with muslin tops. Individual insects were reared in small glass-bottomed pill-boxes, 1-in. diameter and ½ inch deep, secured over the under-surface of the *Malva* leaves, which were reversed so that their under-surfaces were uppermost. (Fig. 1.)

The life-cycle at constant temperatures was carried out in small constant-temperature rooms controlled to within 0·5°C. The source of light for temperatures above 15·6°C. was one 1,000-W. clear electric lamp placed 2 feet above the plants. Heat from this lamp was dissipated by a stream of water running over the glass top of the room.

* An officer of the Council's Division of Economic Entomology.

† Common names used throughout this paper have been taken from a list of proposed standardized names to be published in a forthcoming Bulletin of the Council.

FIG. 1.—Cage used for breeding *Thamnotettix argentata* showing (A) a glass bottomed pill-box, (B) cotton-wool pad beneath the leaf, (C) cardboard square pressing cottonwool and leaf against the open edge of the pill-box, (D) steel spring, and (E) the holder made from 10 inches of $\frac{1}{8}$ inch black iron rod with a $2\frac{1}{4}$ inch iron washer welded to the top. The plant is *Malva parviflora*.

Refrigeration was used to obtain temperatures of 11° and 15·6°C. and the source of cool light was one white fluorescent electric lamp 36 inches by 1 inch, 30-W. (Mazda T8). Plants were placed as close as possible to this source of light. In all experiments plants were arranged to receive approximately 500 foot candles of light.

3. Distribution of *T. argentata*.

The insect was reported from Southern Queensland by Evans (2) and from Western Australia by Norris*. During the course of the work on yellow dwarf it was collected from many districts of New South Wales and Victoria.

4. Host Plants.

Leaf hoppers were collected from a wide range of host plants, but nymphs were found on comparatively few. Apparently adults can survive for long periods on plants unfavourable for oviposition and nymphal development. Most of the host plants on which the hoppers breed freely germinate in the early autumn, grow slowly through winter, and die off in late spring. There are, however, several perennials that

* Unpublished data.

continue to grow throughout the summer and also summer-growing annuals that make rapid growth after rains or in irrigated areas. In the list given below, some of the host plants on which nymphs failed to complete their development may be suitable breeding plants under other conditions.

The insect has been observed to complete its life-cycle on the following plants:—

Continuous Hosts.

Malva parviflora Malvaceae (small-flowered mallow).
Modiola caroliniana (L.) Don. Malvaceae (red-flowered mallow).
Beta vulgaris L. Chenopodiaceae (sugar beet).

Autumn to Spring Hosts.

Medicago denticulata Willd. Leguminosae (burr medic).
Trifolium repens L. Leguminosae (white clover).
*T. subterraneum** L. Leguminosae (subterranean clover).
Cryptostemma calendulaceum (L.) Br. Compositae (capeweed).
*Hypochaeris radicata** L. Compositae (cat's paw or flatweed).
Erodium cicutarium (L.) L'Herit. Geraniaceae (common crowfoot).
*E. cygorum** Nees Geraniaceae (blue crowfoot).
*Sisymbrium orientale** L. Cruciferae (Indian hedge mustard or wild mustard.

Summer Hosts.

Chenopodium carinatum Chenopodiaceae (keeled goosefoot).
*Heliotropium europeum** L. Boraginaceae (common heliotrope).
*Datura stramonium** L. Solanaceae (common thorn apple).
*Solanum laciniatum** Ait. Solanaceae (kangaroo apple).
*S. melongena** L. Solanaceae (egg plant).
*S. nigrum** Auct. Aust. non. L. Solanaceae (nightshade).
Portulaca oleraceae Portulacaceae (pigweed or purslane).
*Bursaria spinosa** Cav. Pittosporaceae (Australian blackthorn)

Eggs hatched in the following plants, but the nymphs failed to become adults:—

*Nicotiana tabacum** L. Solanaceae (tobacco) rare.
*Solanum tuberosum** L. Solanaceae (potato) rare.
*Medicago sativa** L. Leguminosae (lucerne) rare.
*Cystisus proliferous** L. Leguminosae (tree lucerne or tagasaste).
*Polygonum aviculare** L. Polygonaceae (wireweed).
*Cucumis myriocarpus** Naud. Cucurbitaceae (paddy melon).
*Chenopodium alba** L. Chenopodiaceae (fat hen).
*Eucalyptus rostrata** Schlecht Myrtaceae (river red gum).

No nymphs were recorded from:—

*Lycopersicum esculentum** Mill. Solanaceae (tomato).
*Paspalum dilatatum** L. Gramineae (paspalum).
Secale cereale L. Gramineae (rye).
Hordeum sp. Gramineae (barley).
*Marrubium vulgare** L. Labiatae (horehound).
Nicotiana glauca Graham Solanaceae (tree tobacco).
N. suaveolens Lehm. Solanaceae (native tobacco).

* Hill, unpublished data.

5. Life-Cycle.

(i) *Oviposition.*—Oviposition begins three to seven days after emergence, depending on the time of the year. It takes place at any time of day when temperatures are above 15·6°C. In the process the female cuts an incision in the stem, petiole, or main-rib with her ovipositor and a single egg is laid in a slit-like egg chamber. This is difficult to see at first, but after three or four days it appears as a small glistening lump or as a darker portion of the stem or petiole, e.g., *M. parviflora.*

(ii) *The Egg.*—The average length of the egg is 0·8 mm. and average width 0·3 mm. It is elongated and when first deposited it is clear. During embryonic development it turns an opaque cream and after several days the eyes become visible as two red spots. As it nears hatching the embryo enclosed in its embryonic membranes protrudes from the mouth of the egg chamber. In the laboratory the incubation period varied from 7 to 22 days.

(iii) *The Nymph.*—During eclosion the nymph enclosed in its embryonic membranes pushes out of the egg chamber and remains suspended by the tip of the abdomen until it has freed itself and the chitin has hardened. The newly-hatched nymph is cream with two bright red eyes and measures 1·8 mm. in length.

There are five instars, the duration of which varies according to host plant and time of the year. In the laboratory from October to March each instar averaged five days with a total nymphal feeding period of 25 days. The colour of individual instars varies from cream or a light orange to a dark grey, with or without a definite pattern. The wing-pads become visible in the third instar. Full-grown nymphs measure 2·8 to 3·4 mm. in length.

The early instars do not wander very far from the point of hatching but remain feeding in the phloem on the undersurface of the leaf, or on young petioles. Moulting appears to take place anywhere on the plant, usually on a petiole or undersurface of a leaf.

(iv) *The Adult.*—The adult is described by Evans (3) as follows:—"Length of female 3·2 to 3·5 mm.; length of male 2·9 to 3·0 mm. Head pale yellow, marked with an irregular dark-brown pattern; eyes dark-brown. Pronotum, anterior third pale yellow, posterior two-thirds grey, flecked with transverse dark-brown markings. Scutellum, yellow, but for the apex, which is dark brown. Tegmen, hyaline, with a silvery appearance, due to the sheen of the underlying wings, patterned with an irregular network of dark-brown markings. Thorax and abdomen ventral surface, pale yellow with scattered dark-brown markings."

(v) *Habits of the Adult.*—The adult feeds like the nymph. When disturbed it makes a short, rapid flight, but is seldom seen flying during the day unless disturbed. Mass flights were observed around lights at Shepparton, Victoria, on the nights of December 18, 1940, and February 21, 1941, after hot days. The minimum temperature on the night of December 18 was 84°F. (28·9°C.) and that of February 21 77°F. (25°C.) following a day maximum of 100°F. (37·8°C.). The temperature at the time of flight, 10 p.m. on February 21, was 86°F. (30°C.) and relative humidity 84 per cent.

Copulation takes place soon after emergence, and in the laboratory at Shepparton, Victoria, during the months of October to March was followed by a pre-oviposition period of three to seven days. The reproductive capacity of the female is not known, but each female laid an average of six eggs per day for several months.

A male which emerged in the laboratory at Shepparton on February 21, 1941, lived for 125 days, and a female which emerged on February 20, 1941, lived for 240 days. This female produced progeny until the end of May and after a break during the winter resumed oviposition at the end of August and continued depositing viable eggs until just before death. These eggs hatched and the progeny reached maturity. No access was had to a male after June 26, 1941.

Adults are, therefore, long-lived and females fertilized in the autumn can resume oviposition in the spring without further access to males.

Observations on the manner of overwintering were made out-of-doors at Canberra, A.C.T., as follows:—

(*a*) Thirty males and females, enclosed in a muslin bag over a potted *Malva* plant, gradually died off with the cold, the last individual dying on March 28, 1941, 56 days later.

(*b*) Twenty-five third, fourth, and fifth instars, treated in the same manner on May 16, 1941, all died after a severe frost 55 days later.

(*c*) One hundred males and females placed on six *Malva* and three capeweed plants covered with a muslin cage 26 inches x 26 inches x 20 inches survived from May, 1941, throughout the winter until September 9, when the mat of vegetation became too thick to find the insects.

(*d*) Six females and one male placed on a muslin-enclosed *Malva* plant produced first generation adults by the end of November, when one original female survived.

(*e*) Hill collected adults from capeweed and wheat at Numurkah and Shepparton, Victoria, early in August, 1940, and several adults and two fifth instar nymphs from *Malva* plants at Numurkah about the same time in 1941.

Thus at Canberra, where the winters are cold, the insects overwintered in the adult stage, whereas in warmer districts such as Northern Victoria the adults and late instars overwintered. It was observed at Canberra that adults sheltered from severe frosts in cracks in the ground and among debris beneath plants and did not emerge until late in the morning. Females fertilized in the autumn deposited eggs at the end of August, producing first generation adults from the middle of October to the end of November.

6. Number of Generations.

In Northern Victoria three complete generations a year were observed both in the field and in the laboratory. The generations overlapped and breeding was continuous as long as temperatures were suitable and host plants available.

7. Life-Cycle at Constant Temperatures.

The life-cycle of the insect on *Malva* plants was studied at four different constant temperatures. Nymphs maintained at a constant temperature at 11°C. failed to complete development, and all eggs used in the experiment died after developing to the red eye stage. Oviposition ceased at temperatures below 15·6°C. The results are shown in the table:—

Temperature °C.	Incubation Period.			Feeding Period.			Total Life-cycle.		
	Max.	Min.	Mean.*	Max.	Min.	Mean.*	Max.	Min.	Mean.*
11° ..	..	..	..	..	..	..	..	..	..
15·6° ..	28·7	25·7	27·2	71·7†	71·7†	71·7†	100·7†	100·7†	100·7†
22·0° ..	16·7	10·7	13·6	35·7	23·7	27·2	51·7	37·7	43·0
28·0° ..	9·7	6·7	8·0	18·7	13·7	15·8	29·7	22·7	25·2
34·0° ..	7·7	3·7	5·6	17·7	9·7	11·8	23·7	13·7	16·8

* The harmonic mean for each stage is the reciprocal of the mean velocity for all individuals at a given temperature, and is used because the distribution of points became more widely dispersed as the temperature rose.

† Two readings only.

From the above data it is possible to obtain the relationship between temperature and velocity of development at temperatures above 22°C. A knowledge of this relationship is of practical value when studying the ecology of the insect. It is also possible to obtain the maximum value for the zero of development for the incubation and feeding periods. It is not possible to determine the optimum temperature, but

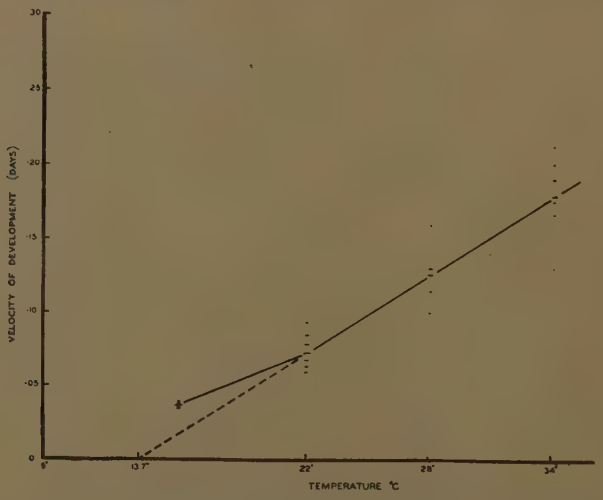


FIG. 2.—*T. argentata.* Temperature velocity of development line for the incubation period; the reciprocals of duration (in days) of the incubation period are plotted on the ordinate.

observations suggest that it lies between 22°C. and 28°C. Figs. 2, 3, and 4 show the velocity of development lines for the incubation, feeding and total development periods at temperatures 15·6°C., 22°C., 28°C., and 34°C. The maximum values for the zero of development for the

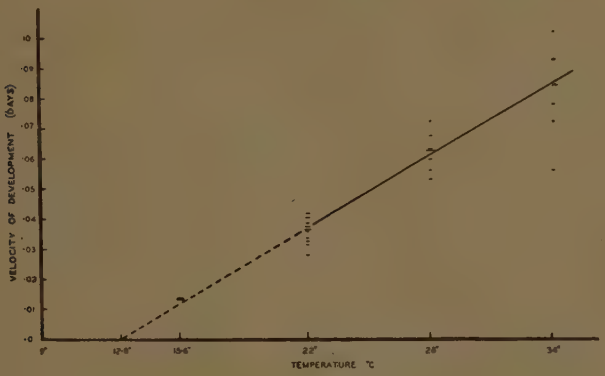


Fig. 3.—*T. argentata*, temperature velocity of development line for the feeding period. The reciprocals of duration are plotted as in Fig. 2.

incubation, feeding and total developmental periods are here shown to be 13·7°C., 12·8°C. and 14·4°C., respectively. The zero of development for the total developmental period lies outside the zeros for the incubation and feeding periods mainly because all individuals of the incubation period were not observed through the feeding period.

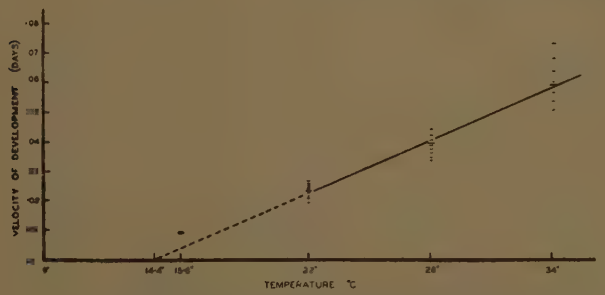


Fig. 4.—*T. argentata* temperature velocity of development line for total developmental period. The reciprocals of duration are plotted as in Fig. 2.

8. Ecology.

During the 1940-41 season, the insect was observed at Gunbower, Nathalia, Shepparton, and in the Ovens Valley. It was most abundant in the spring, reaching a peak at the end of November, 1940. In the

field the insect was observed on the following plants, all of which occur in tobacco-growing areas:—

Medicago denticulata (burr medic).
Cryptostemma calendulaceum (capeweed).
Erodium sp. (crowfoot).
Malva parviflora (small-flowered mallow).
Modiola caroliniana (red-flowered mallow).
Chenopodium carinatum (keeled goosefoot).
Polygonum aviculare (wireweed).
Trifolium repens (white clover).
Bursaria spinosa (Australian blackthorn).

Red-flowered mallow and *Malva* are biennials and suitable host breeding plants at all seasons; the annuals burr medic, capeweed, and crowfoot suitable autumn, winter, and spring host breeding plants; and white clover (in irrigated districts), keeled goosefoot, and *B. spinosa* suitable summer hosts. The latter is perhaps an important host in inland districts during the hot dry months when suitable summer annuals are not available. The annuals died off about the end of November, 1940, and were replaced later by keeled goosefoot. In dry districts, however, there were few host breeding plants from the time the winter ones died until the summer ones struck, and at this time there was a high nymphal mortality. At this time also adults migrated, some moving into the tobacco crop on which they seemed to survive until more suitable plants were available. In irrigation areas the winter hosts survived longer and the summer ones appeared earlier, so that there was a lower nymphal mortality in such places.

Wherever host breeding plants grew continuously throughout the summer, as in the middle and upper reaches of the Ovens Valley and in irrigated areas, the insect apparently bred continually, but where dry conditions prevailed and few summer breeding hosts struck, the insect carried through the hottest, driest months of the summer in the adult stage feeding on any available green plants. After the first showers of rain on December 28, 1940, and the heavier rain on January 3, 1941, keeled goosefoot and burr medic plants appeared in the dry areas, and females immediately began ovipositing on the seedling plants.

Field Observations at Nathalia, Victoria, from October, 1940, to March 1941.

During this time the succession of insects and host breeding plants was observed on one particular field and on seedbeds in the town of Nathalia.

Nathalia is a dry district where the weeds and pastures surrounding the tobacco fields die at the end of spring and the tobacco crops are grown with the aid of irrigated water.

At the end of October all stages of the insect were present in the seedbeds and on the weeds surrounding the area of ground prepared for transplanting. At this time the following plants were present in or near the seedbeds:—

Erodium sp. (crowfoot),
Chenopodium alba (fat hen),
Chenopodium carinatum (keeled goosefoot),

Solanum nigrum (nightshade),
Cryptostemma calendulaceum (capeweed), dying,
Sisymbrium orientale (Indian hedge mustard) and *S. officinale* (hedge mustard),
Malva parviflora (small-flowered mallow),
and the following near the field:—
Erodium sp. (dying),
Cryptostemma calendulaceum (dying),
Malva parviflora,
Bursaria spinosa.

The crop had not been planted and nymphs in all stages of development were very abundant on the crowfoot and capeweed. Adults were very few in number.

Planting of the tobacco crop began on November 2, 1940, at which time the crowfoot was almost dead and nymphs of all stages were abundant on capeweed. A few adults which were apparently carrying the virus were taken on tobacco seedlings which had just been planted. By the end of the third week in November fourth and fifth instar nymphs were feeding on the few surviving capeweed. A heavy mortality of nymphs appears to have taken place about this time, and adults were more abundant on the tobacco crop. On November 28 no nymphs could be found, but large numbers of adults were collected from young tobacco plants, some of which were showing signs of yellow dwarf disease. As the number of adults was noticeably reduced by the middle of December, this appears to have been the peak of the first generation. At this time there was a lack of host breeding plants of any kind, the only green plants being *Eucalyptus rostrata*, *B. spinosa* and the tobacco crop.

At the end of November and until the middle of December, however, adults were still abundant at the seedbeds where capeweed, *Malva*, wireweed, and keeled goosefoot were all growing vigorously as a result of watering. Small numbers of nymphs were observed here during December and January.

Throughout December the ground surrounding the field remained dry and without vegetation, and most weeds which grew in the crop were destroyed by cultivation. During this time no nymphs could be found, but a small number of adults persisted on the tobacco crop. On January 7, 1941, burr medic, *Malva*, and keeled goosefoot were common in the vicinity of the crop following rains at the end of December and beginning of January. The adults formerly feeding on tobacco moved on to these weeds, and the females, many of which had emerged at the end of November, began ovipositing almost as soon as the seedlings appeared above the ground. As a result, nymphs of all ages were very abundant on February 4, especially on keeled goosefoot, and newly-emerged adults of the second generation were becoming abundant on the weeds, but none could be found on the tobacco. The mat of weeds at this time was up to 6 inches high.

The peak of the second generation adults came in the third week of February and large numbers were observed around lights at Shepparton on the nights of February 21 and 22, 1941. At this time crowfoot and capeweed had appeared, and adults of the second generation began ovipositing on these two hosts. In the middle of

March nymphs of the third generation were abundant at Nathalia and Shepparton, developing on crowfoot, burr medic, *Malva*, and keeled goosefoot. Adults of the third and overwintering generation emerged at the end of March, at which time keeled goosefoot had died off and breeding continued on capeweed and crowfoot.

9. Acknowledgments.

It is a pleasure to acknowledge thanks to G. A. McIntyre for statistical analyses, to A. V. Hill for making available unpublished data, to W. Hartley for plant identifications, and to Dr. A. J. Nicholson and F. N. Ratcliffe for perusing the manuscript.

10. References.

1. Hill, A. V.—*J. Coun. Sci. Ind. Res.* (Aust.), **14**: 181-186, 1941.
2. Evans, J. W.—*Proc. Roy. Soc. Q'ld. for* 1940, 52: 10-13, 1941.
3. Evans, J. W.—*Proc. Roy. Soc. Tas. for* 1938, p. 15, 1939.

Scientific Papers from the Division of Food Preservation and Transport Published Elsewhere than in the Council's Publications.

Erratum.

An error occurred on page 34 of this article, which appeared in the previous issue. In the section headed "**C. Fish**" the title of the abstract should have read:—

Collins, V. K., Kuchel, C. C., and Beatty, S. A. (1941).—Studies of Fish Spoilage. 9. Changes of Buffering Capacity of Cod Muscle Press-juice. *J. Fish. Res. Bd. Canad.* 5: 203.

PLATE 1.

(Studies on Mineral Metabolism in Sheep. See p. 85.)

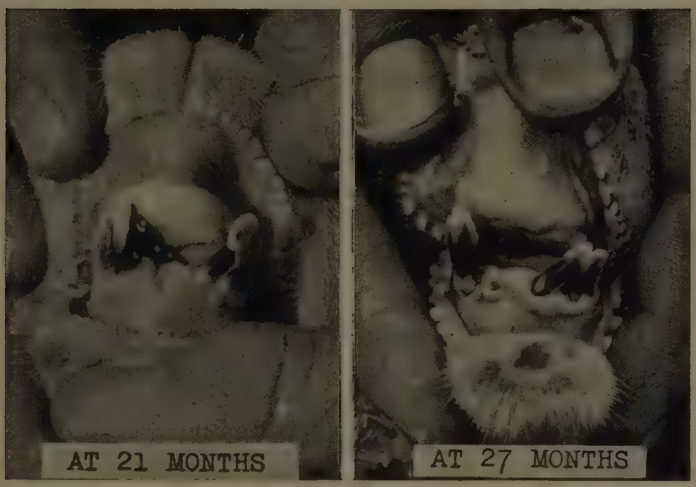


FIG. 1.—Showing the incisor teeth of A504 (basal ration only) at 21 months and 27 months. Persistent deciduous teeth showing abnormal wear, displacement and discoloration, with some thickening of the marginal gum. Complete failure of permanent teeth to erupt.

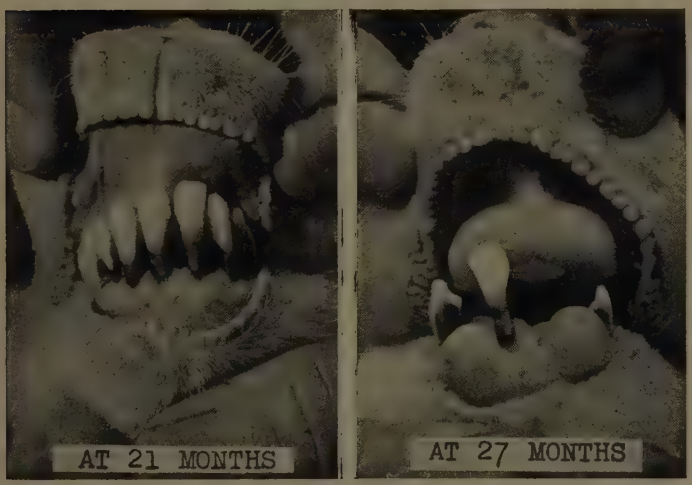


FIG. 2.—Showing the incisor teeth of A508 (basal ration + oxalate then basal ration + calcium carbonate) at 21 and 27 months. At 21 months there is a full set of deciduous teeth, discolored at the base, and recession of the gums. At 27 months there is uneven shedding of deciduous teeth and commencement of eruption of central incisors.

(Studies on Mineral Metabolism in Sheep. See p. 85.)

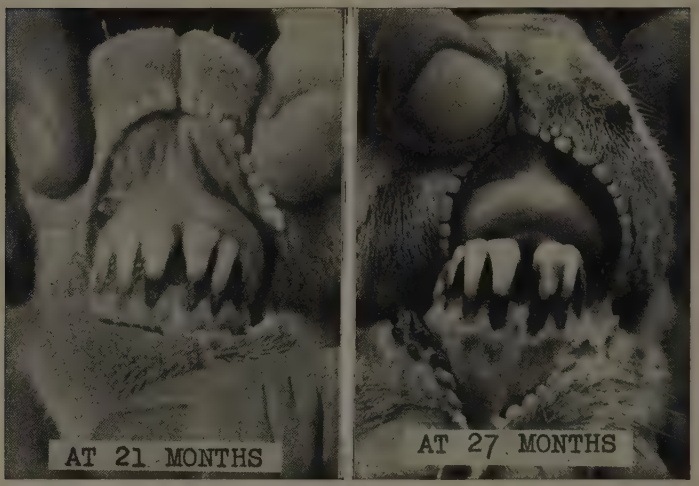
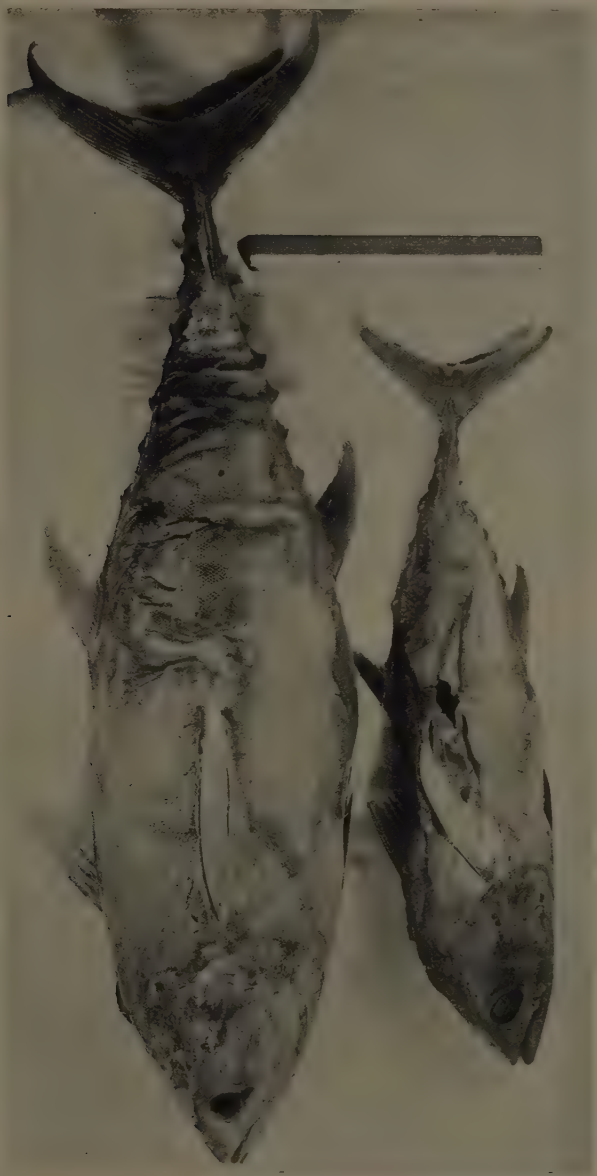


FIG. 1.—Showing the incisor teeth of A989 (basal ration then basal ration + calcium carbonate) at 21 months and 27 months. There is little change in the 6 months interval.

FIG. 2.—Showing normal development of incisor teeth of A983 (basal ration + 1 per cent. of calcium carbonate) at 21 months, and at 27 months when it was a 6-tooth.

PLATE 3.

(The Tuna *Kishinoella tonggol* Bleeker in Australia. See p. 101.)



[*Photo by courtesy of Dr. F. P. Koumans, December, 1939.*

Bleeker's type material of *Thynnus tonggol* at the Leiden Museum, Holland.

(The Tuna *Kishinoella tonggol* Bleeker in Australia. See p. 101.)

FIG. 1.—Northern tuna (*Kishinoella tonggol*), Port Hacking, New South Wales, 3rd April, 1941. Length 95·5 cm.

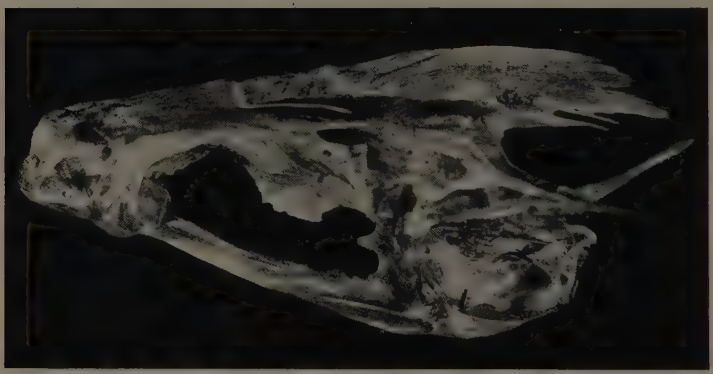
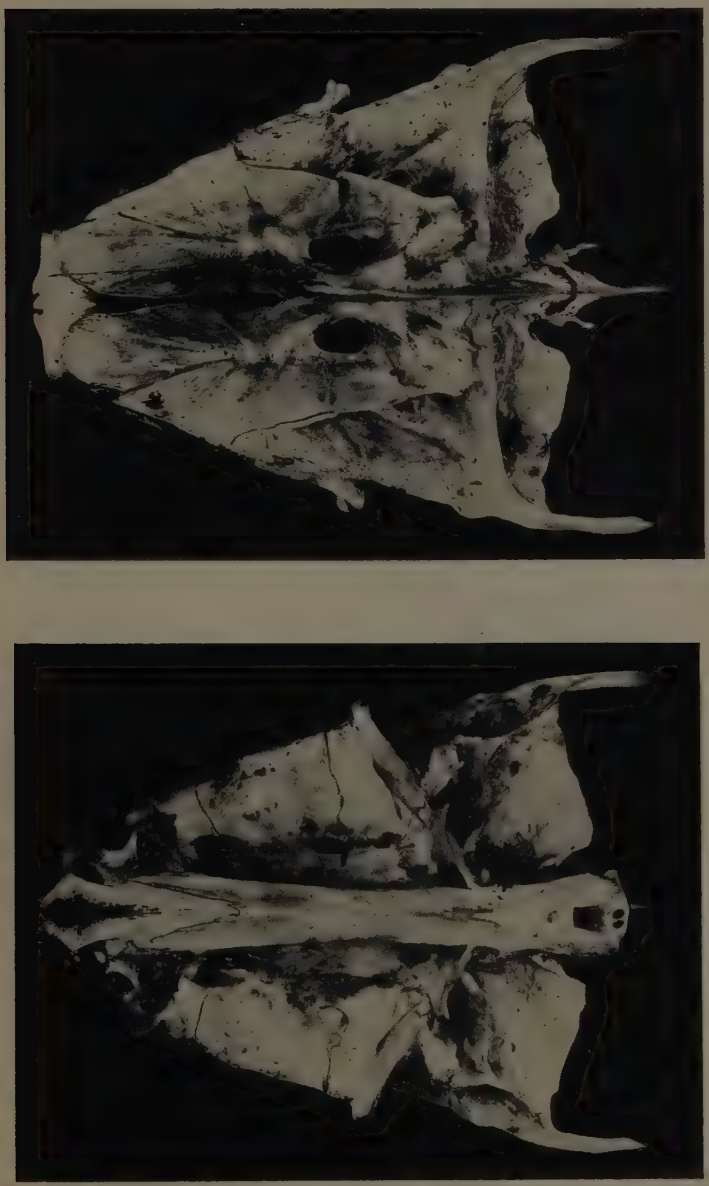


FIG. 2.—Cranium and first vertebra of *Kishinoella tonggol*, lateral view.

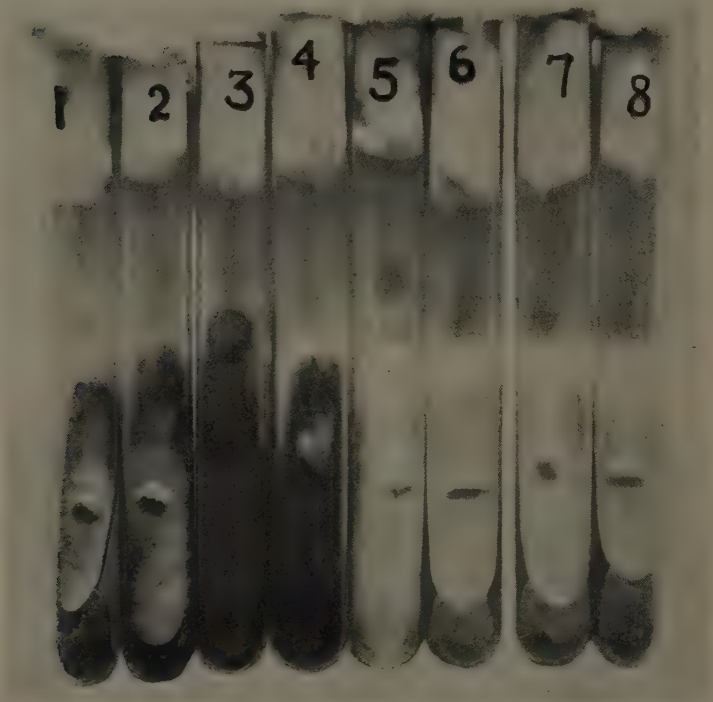
PLATE 5.

(The Tuna *Kishinoella tonggol* Bleeker in Australia. See p. 101.)



Cranium of *Kishinoella tonggol*, showing dorsal view (above) and ventral view (below).

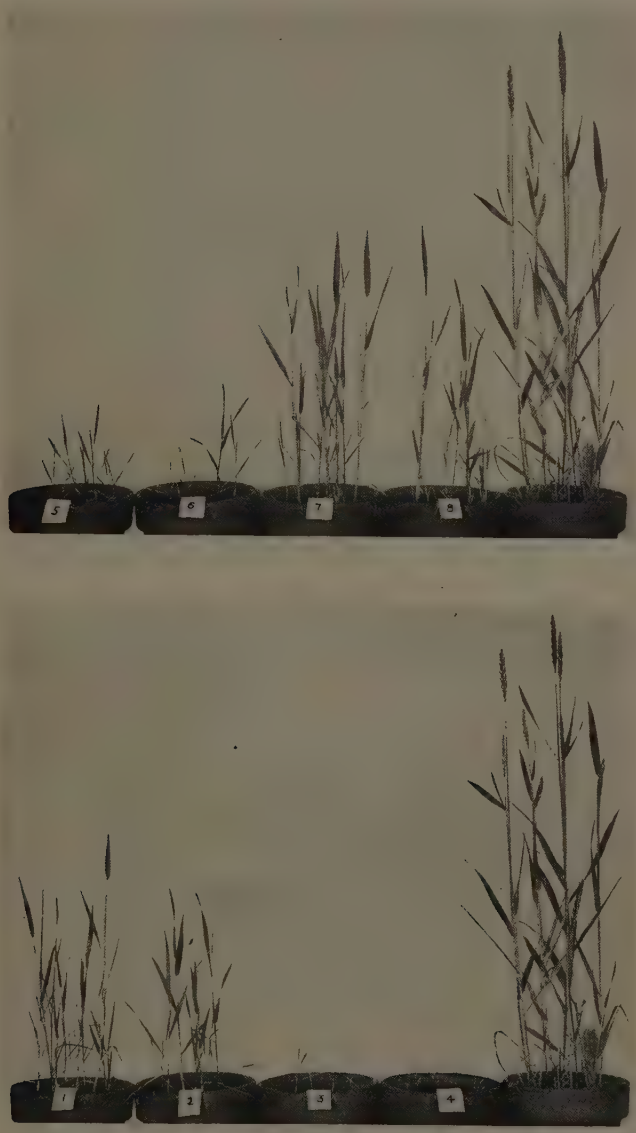
(The Genetics of *Ophiobolus graminis* Saac. See p. 118.)



Culture colour variations of the eight isolates from a single ascus of *O. graminis*.

PLATE 7

(The Genetics of *Ophiobolus graminis* Saac. See p. 118.)

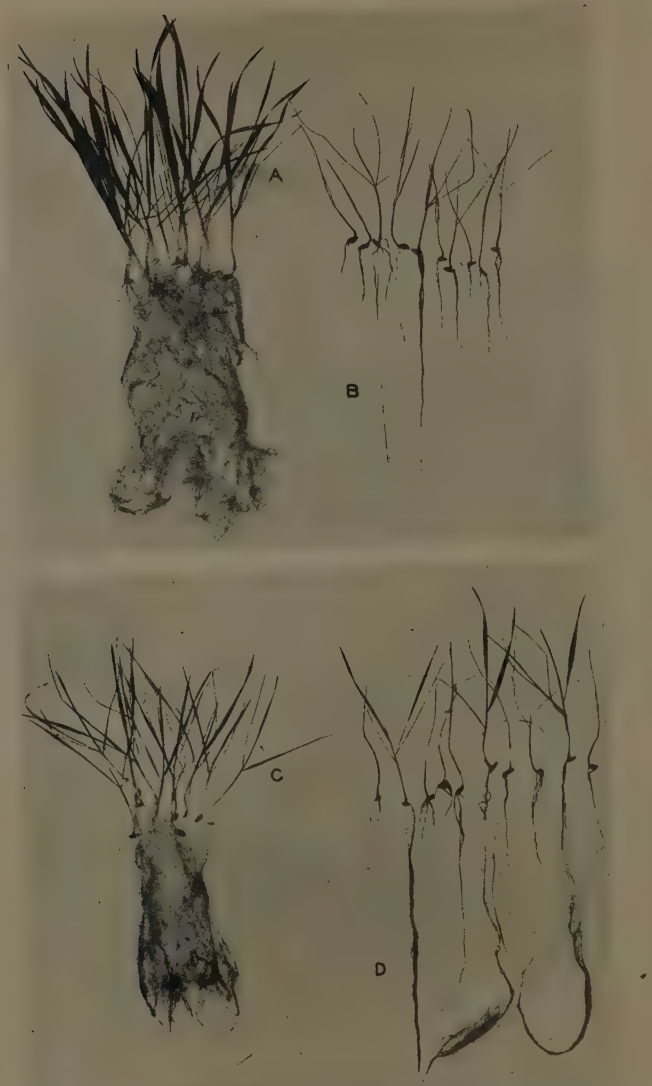


Pathogenieity for variations of the eight isolates from a single ascus of *O. graminis*.

The numbers on the pots refer to the isolates of *O. graminis* and the pot on the right in each figure is the control.

PLATE 8.

(See p. 124.)



Effects of sodium chloride and of inoculation with *Ophiobolus graminis* on the growth of wheat seedlings. Photographed eight weeks after sowing.

A = Untreated—10 plants healthy, tops green, av. ht. 7 ins.

B = Soil inoculated with *O. graminis*—5 plants dead, 5 alive but very weak, av. ht. 3·5 ins., roots badly discoloured.

C = Five grammes of NaCl per can—1 plant dead, 9 alive but weak ; older leaves yellow ; av. ht. 5 ins.

D = NaCl plus *O. graminis*—7 plants dead, 3 alive, av. ht. 4·5 ins. Roots less discoloured than those of B. Tops similar to those of C.

NOTES.

Recent Publications of the Council.

Since the last issue of the *Journal*, the following publications of the Council have been issued:—

Bulletin No. 142.—"A Soil and Land Use Survey of the Hundreds of Riddoch, Hindmarsh, Grey, Young, and Nangwarry, County Grey, South Australia," by C. G. Stephens, M.Sc., A.A.C.I., R. L. Crocker, M.Sc., B. Butler, B.Ag.Sc., and R. Smith, B.Ag.Sc.

The survey described in this Bulletin covers about 500 square miles of County Grey, in the south-eastern corner of South Australia. It was undertaken by the Division of Soils at the suggestion of officers of the Woods and Forests Department of South Australia, who required the information as a basis for experimental work in their forest plantations and for use in land selection and soil type control in their pine plantation programmes.

Soil surveys in this and similar rainfall areas in South Australia are of considerable importance, as it is considered that any marked increase in population in South Australia would have to be accommodated in the higher rainfall areas. Such surveys should make it a relatively simple matter in these areas to guide development along the most efficient and productive lines. The present survey, in which also the different types of land use were recorded, has indicated that the great variation in pasture production and the haphazard use of fertilizers, even on the better soils, is not justified. Simply by correctly using the soil resources available and applying present pastoral and fertilizer knowledge the productivity can be markedly and immediately increased.

Bulletin No. 144.—"Interference in a Wind-Tunnel of Octagonal Section," by G. K. Batchelor, M.Sc.

The influence of the walls of a wind-tunnel of rectangular, circular, or elliptic cross-section on the behaviour of a model is well known. In recent years, however, many tunnels of octagonal cross-section have been constructed, and the new wind-tunnel of the Council's Division of Aeronautics, Melbourne, is of this design. It was therefore necessary to calculate the interference on a model of small wing-span suspended at the centre of a closed tunnel of irregular octagonal section. The calculations involved are given in the present Bulletin and show that the induced velocity due to the walls is a little greater than that in a rectangular tunnel of the same over-all dimensions. A calculation is also made of the interference on a model of finite wing-span and arbitrary wing loading. The method used throughout involves the usual doubly-infinite array of images as for a rectangular section, with the addition of vortex rows of given strength.

Bulletin No. 145.—"Friction and Lubrication, Report No. 1. 1. The Theory of Metallic Friction and the Role of Shearing and Ploughing. 2. The Friction of Thin Metallic Films," by F. P. Bowden, Sc.D. (Cantab.), and D. Tabor, Ph.D. (Cantab.).

According to the theory of metallic friction put forward in earlier papers, the frictional resistance between two metals sliding over one another is due primarily to the shearing of the metallic junctions which are formed at the points of contact, and to the work of dragging or ploughing the surface irregularities of the harder metal through the softer one. The first paper of Bulletin 145 describes an attempt to put this theory on a more quantitative basis and to calculate the friction in terms of the known physical properties of the metals. The experiments show that the friction between the metals is determined by the real area of contact; the load is important mainly in so far as it affects this area. The second paper describes an investigation of the frictional properties of thin films of indium, lead, and copper deposited on to the surface of other metals, and the results are in agreement with the theory put forward in the previous paper.

Bulletin No. 147.—"Enzootic Ataxia and Copper Deficiency of Sheep in Western Australia," by H. W. Bennetts, D.V.Sc., and A. B. Beck, M.Sc.

This Bulletin describes work done in co-operation with the Western Australian Department of Agriculture on copper deficiency of sheep in Western Australia. This deficiency is shown to be the cause of enzootic ataxia in lambs, "stringiness" of wool in adult sheep, and anæmia, diarrhœa, and loss of bodily condition in breeding ewes.

Enzootic ataxia of lambs, also known as "gingin rickets," is characterized by degeneration of the spinal cord and other parts of the nervous system, usually before birth; this is responsible for the ataxia, which frequently only affects the hind limbs. The disease is confined to the progeny of ewes which have been depastured continuously for at least six months on "affected" country. It has been found that the provision of copper sulphate licks in such areas completely prevents the occurrence of ataxia in lambs and keeps adult sheep in good health. Experiments indicate that top-dressing pastures with 10 to 20 lb. of copper sulphate per acre may be just as effective as providing licks.

Pamphlet No. 110.—"The Main Virus Diseases of the Potato in Victoria," by J. G. Bald, M.Agr.Sc., Ph.D., and A. T. Pugsley, B.Agr.Sc.

This Pamphlet contains the results of a survey carried out in co-operation with the State Departments of Agriculture, and particularly the Victorian Department. The experiments and observations described were carried out over a period of five years. Their object was to determine what viruses were present in Victorian potatoes, and to discover their reactions on the commonly grown varieties, and their incidence in the various potato-growing districts of the State. The four main types of virus were found to be: Virus X, which is present in nearly every plant of the commoner varieties of potatoes; virus A, which causes mild mosaic; virus Y, which causes rugose mosaic; and, fourthly, the virus that causes leaf roll. Virus X may be transmitted by contact between the foliage of diseased and healthy plants, but the other three viruses are transmitted exclusively by various kinds of aphis.

Pamphlet No. 111.—"The Biology and Cultivation of Oysters in Australia. 2. A note on the Calcium Content of Some East Australian Waters. 3. Biochemistry of the Proximate Constituents," by G. Humphrey, M.Sc.

This pamphlet describes attempts to solve some of the problems that confront oyster farmers. An inquiry has been made into the reason why oysters reach marketable size much more quickly in some localities than in others. It was thought that some waters might be too low in calcium to allow rapid growth of the shell, but sampling showed that the water varied little in its calcium content. Another problem is to find what governs the condition, or "fatness," of an oyster. Oysters in good condition are rich and creamy and fill the shell completely, whereas those in poor condition are watery, glassy, and only partly fill the shell. Unfortunately, the appearance of good condition can be neither predicted nor regulated, and oysters have been known to lose condition almost overnight. Some authorities have asserted that fatness is determined by the amount of glycogen in the oyster, but work described in the present pamphlet shows that the fattest oysters occur just before spawning when the glycogen content is at its lowest. It seems likely that the glycogen is stored as a reserve food material. Further experimental work is being carried out.

Pamphlet No. 112.—"Building-Frames. Timber and Sizes," by A. J. Thomas, Dip. For., and Ian Langlands, M.Mech.E., B.E.E., A.M.I.E. Aust.

This Pamphlet summarizes information on the use of Australian timbers for the framework of buildings. In the past there has been no distinction between kinds of timbers, and all grades have been regarded as no better than the lowest; these views, with precedent and overseas practice as a guide, have resulted in the use of unnecessarily large sizes of timber and thus useless waste and expenditure. The purpose of the present Pamphlet is to promote economy by indicating how timber can be used to its best advantage. The mechanical and physical properties of the timber, its durability, availability, and price, must all be taken into account if the best use is to be made of available supplies. The Pamphlet shows the timbers available in the different States and tabulates the sizes required for the various members in a building, both for first-class dwellings and for temporary or second-class buildings. The increased demand for structural timbers created by the war effort has made very clear the fact that large savings can be effected by the most economical use of timber, and has emphasized the need for such savings.

Circular No. 4-*P.*—"Notes on the Application of Refrigeration to the Australian Fishing Industry."

This Circular, written in non-technical language, has been prepared by the Division of Food Preservation and Transport to serve as a guide to the fish industry on the basic refrigeration requirements. Some means of cooling fish should be used in all fishing boats. Ice enables fish to be kept for several days and remain satisfactory for most purposes, but when the catch is intended for quick-freezing and long storage in the frozen condition, the time on ice should be as short as possible, preferably less than 24 hours. Quick-frozen fish, when treated promptly after catching, and stored at a temperature of 0 deg. F. or lower, may be kept in good condition for several months. Fish stored for canning or for a short time only can be kept at 10 deg. to 15 deg. F., and need not be frozen so rapidly. Freezing is particularly valuable for such fish as sharks, which normally deteriorate rapidly if not consumed within 36 hours.

Forthcoming Publications of the Council.

At the present time, the following future publications of the Council are in the press:—

Bulletin No. 146.—"An Analysis of the Outbreaks of the Australian Plague Locust (*Chortoicetes terminifera* Walk.) during the Seasons 1937-38 and 1938-39," by K. H. L. Key, M.Sc., Ph.D.

Bulletin No. 148.—"Studies in Fertility in Sheep. II. Seminal Changes Affecting Fertility in Rams," by R. M. C. Gunn, D.V.Sc., B.Sc.Agric., M.R.C.V.S., R. N. Sanders, B.V.Sc., and W. Granger, B.V.Sc.

Bulletin No. .—"Production of Dried Grapes in Murray Valley Irrigation Settlements. 2. Irrigation, Drainage, and Reclamation," by A. V. Lyon, M.Agr.Sc., and A. L. Tisdall, M.Agr.Sc.

Bulletin No. .—"The Control of St. John's Wort (*Hypericum perforatum* L. var. *angustifolium* D.C.) by Competing Pasture Plants," by R. M. Moore, B.Sc.Agr., and A. B. Cashmore, M.Sc.

Bulletin No. .—"Pelagic Tunicates in the Plankton of South-eastern Australian Waters, and their Place in Oceanographic Studies," by H. Thompson, M.A., D.Sc., with a Statistical Analysis of Data on Total Plankton, by G. L. Kesteven, B.Sc.

Bulletin No. .—"Standardized Plant Names. A List of Standard Common Names for the more Important Australian Grasses, other Pasture Plants, and Weeds," prepared by the Division of Plant Industry.

Bulletin No. .—"The Soils of the Parishes of Longford, Cressy, and Lawrence, County Westmorland, Tasmania. 1. A Soil Survey of the Area. 2. Pot Experiments with Subterranean Clover on the Cressy Shaley Clay-loam," by C. G. Stephens, M.Sc., A.A.C.I., J. G. Baldwin, B.Agr.Sc., and J. S. Hosking, M.Sc., A.I.C.

Bulletin No. .—"Soil Survey of Part of County Moira, Victoria, including the Parishes of Boosey, Cobram, Katamatite, Naringaninga-look, Katunga, Yarroweyah, and Strathmerton," by B. E. Butler, B.Sc.Agr., J. G. Baldwin, B.Ag.Sc., F. Penman, M.Sc., and R. G. Downes, M.Ag.Sc.

Pamphlet No. 113.—"Drainage Investigations in the Horticultural Soils of the Murray Valley," by A. L. Tisdall, M.Agr.Sc.

Pamphlet No. 114.—"Plant Introduction. 1. A Review, with Notes on Outstanding Species," by A. McTaggart, Ph.D. "2. Preliminary Selection and Evaluation of Pasture Species at Lawes (Queensland)," by T. B. Paltridge, B.Sc.

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